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In a range from the super-fast 1" — 6 Bar Machine to the big robust 9" — 4 Chucking Machines.

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1¼" BAR CAPACITY — FIVE SPINDLES

1¾" BAR CAPACITY — EIGHT SPINDLES

2¼" BAR CAPACITY — FIVE SPINDLES

2¾" BAR CAPACITY — SIX SPINDLES

3½" BAR CAPACITY — FOUR SPINDLES

6" CHUCK CAPACITY — FIVE SPINDLES

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The solution to a repetition machining problem frequently depends upon the selection of a machine that's ideal for size, power, and speed—in short, just right for the job.

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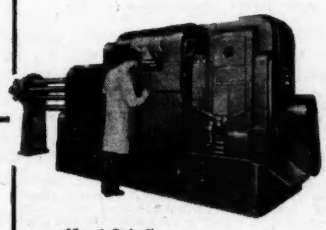

2¾"—6 Spindle Automatic

WICKMAN LIMITED

MACHINE TOOL DIVISION, BANNER LANE, COVENTRY

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364 WM.

THE ENGINEER

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PRINCIPAL CONTENTS

(Complete contents on page 742)

Guided Missiles 742

Thread Inserts 726
(B. CROSSLAND)

Genesis of the Thermionic Valve 745
(PROFESSOR G. W. O. HOWE)

Testing the Performance of Precision Ball Bearings 732
(M. GRANEEK AND H. L. WUNSCH)

Coal Preparation Plant at Mansfield Colliery ... 747

Boundary Layer Control—No. II 751
G. V. LACHMANN)

Iron and Steel Institute—No. I 735

Two-Stroke Oil Engines 742

NOTICE TO READERS

All letters intended for insertion in 'The Engineer or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

SUBSCRIPTIONS

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday th- same week. Orders must be accompanied by a remittance.

INDEX TO ADVERTISERS—PAGE 151

PUBLIC APPOINTMENTS

BOROUGH POLYTECHNIC
BOROUGH ROAD, S.E.1.

DEPARTMENT OF MECHANICAL ENGINEERING

GRADE B ASSISTANT LECTURER

The Governors invite applications from suitably qualified candidates for appointment as a GRADE B ASSISTANT LECTURER in the Department of Mechanical Engineering. Candidates should be Graduates of a British University or possess an equivalent qualification and have had teaching experience either in mechanical or production engineering, and/or good industrial experience.

Salary will be paid in accordance with the scale for Grade B Assistant Lecturers, as provided by the Burnham (Further Education) Report, 1954.

Further particulars and forms of application may be obtained from the undersigned.

DOUGLAS H. INGALL
E6734 Principal.

COUNTY BOROUGH OF ROTHERHAM

EDUCATION COMMITTEE

ROTHERHAM TECHNICAL COLLEGE
Principal : G. E. COOKE, M.A.

ASSISTANT LECTURER (GRADE B)

Applications are invited for the post of ASSISTANT LECTURER (GRADE B) in the Department of Mechanical, Production and Civil Engineering, to teach fabrication of steelwork and/or welding or sheet metalwork, and to take responsibility for the development of this section of the work of the Department.

Candidates should possess suitable qualifications and have had adequate industrial and teaching experience.

Salary will be in accordance with the Burnham Technical Award, 1954, for Grade B, viz., £525 by £25 to £820.

Application forms may be obtained from the undersigned, to whom they should be returned by the 13th December, 1954.

R. BLOOMER,
E6758 Director of Education.

BRITISH ELECTRICITY AUTHORITY

NORTH EASTERN DIVISION

APPOINTMENT OF SENIOR ASSISTANT ENGINEER, GENERATION (OPERATION) DEPARTMENT

Applications are invited for the appointment of SENIOR ASSISTANT ENGINEER in the Generation (Operation) Department at Divisional Headquarters, Newcastle upon Tyne.

The successful candidate will be required to take charge of a section responsible for co-ordinating the mechanical engineering and economical aspects of power station operation and maintenance.

Applicants should have good technical qualifications and practical experience in investigational and project work, though this need not necessarily have been in power stations.

The salary for this appointment (which is superannuable) will be in accordance with the National Joint Board Agreement, Grade 1, Schedule "C," (£1100–£1285 per annum), and will commence at a point commensurate with qualifications and experience.

Forms of application may be obtained from Divisional Establishments Officer, British Electricity Authority, North Eastern Division, Carliol House, Newcastle upon Tyne, 1, to whom they should be returned to arrive not later than 13th December, 1954.
E6742

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

WINDSCALE, SELLAFIELD

ELECTRICAL ENGINEER

U.K. Atomic Energy Authority requires an ELECTRICAL ENGINEER at each of its works at Windscale, Sellafield, Cumberland and Capenhurst, Chester, to be responsible for the maintenance of heavy electrical plant.

Qualifications : Recognised electrical engineering apprenticeship and Membership of Senior Engineering Institution. A Degree in Electrical Engineering may be an advantage and good experience, particularly with high rupturing capacity switchgear and protective systems, is essential. Salary, £620 (at age 25) to £960. The successful candidates will later be required to join the Authority's contributory pension scheme and salaries will be increased to cover the contributions.

Application to United Kingdom Atomic Energy Authority, Industrial Group Headquarters, P.O. Box 19, Risley, Warrington, quoting 737. E6715

LONDON COUNTY COUNCIL

CIVIL ENGINEERS, CIVIL ENGINEERING ASSISTANTS AND DRAWING OFFICE STAFF

CIVIL ENGINEERS, CIVIL ENGINEERING ASSISTANTS and DRAWING OFFICE STAFF, for design of large civil engineering works in connection with main drainage and sewage purification. Salaries within range £300–£739. Application form (returnable within 14 days) from Chief Engineer (54/56), London County Council, The County Hall, S.E.1. (S.A.E.) (1338). E6197

PUBLIC APPOINTMENTS

GOVERNMENT OF THE FEDERATION OF MALAYA

MALAYAN PUBLIC WORKS DEPARTMENT

MECHANICAL ENGINEERS

Vacancies for MECHANICAL ENGINEERS in the Malayan Public Works Department.

The duties are to supervise and organise the staff and workshops engaged in the assembly, erection, maintenance and repair of plant and machinery comprising diesel and steam road rollers, petrol and diesel-engined vehicles, air compressors, stone crushing machinery, earth-moving equipment, diesel and steam pile driving and equipment, pumping machinery, &c.

Appointment is on contract for three years in the first instance in the salary scale £1005–£2044 per annum, point of entry depending on experience and service in the Forces, plus a non-pensionable expatriation allowance for married candidates varying between £91 and £259 per annum. A substantial variable cost-of-living allowance is also payable. A gratuity of £200–£280 per annum is payable on satisfactory completion of contract.

Free first-class passages are provided for the officer, his wife, and up to three children under the age of 10. Furnished quarters, if available, are provided at reasonable rents. Leave is granted at the rate of four days for each month of residential service.

Candidates, between 23 and 35 years of age, should be A.M.I.Mech.E. or have passed or hold a University Degree giving exemption from Parts A and B of the examination for A.M.I.Mech.E., in which case they must become Corporate Members before passing the £1479 point in the salary scale. They should have had at least three years' regular training in an engineering works in drawing-office, machine shop, fitting shop, foundry and pattern shop, and subsequent experience in a large engineering works ; a knowledge of the maintenance and repair of earth-moving equipment an advantage.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number BCD.112/23/01/D4.
E6724

BRITISH ELECTRICITY AUTHORITY

LONDON DIVISION

MAINTENANCE ENGINEER (MECHANICAL)

Applications are invited for the following superannuable post. Conditions of service in accordance with the revised N.J.B. Agreement, Schedule A. Qualifications entitling to Corporate Membership of I.E.E. or I.Mech.E. an advantage.

MAINTENANCE ENGINEER (MECHANICAL), Brunswick Wharf Generating Station (Vacancy No. 54/978).

Wide experience necessary in maintenance of modern generating plant. Duties will include co-ordination of maintenance work and programmes covering the mechanical maintenance of the boiler-house, turbine-house, coal-handling plant, &c. Salary, Class K, Grade 7=£1023 15s. p.a., including London allowance.

Applications, quoting vacancy number, may be made on form obtainable from Divisional Secretary, British Electricity Authority, London Division, P.O. Box 136, Generation House, Great Portland Street, W.1, and be received within 14 days of this advertisement. E6760

NATIONAL COAL BOARD

LONDON HEADQUARTERS PRODUCTION DEPARTMENT

DEPUTY CHIEF ENGINEER (TECHNICAL)

National Coal Board invite applications from Senior Mechanical Engineers for a superannuable appointment as DEPUTY CHIEF ENGINEER (TECHNICAL) in their London Headquarters Production Department. Applicants should be Corporate Members of the Institution of Mechanical Engineers ; have a wide experience in mechanical design ; be receptive to new ideas and be able to adapt known techniques in other industries to the mining industry. The responsibilities include standardisation, the preparation of technical specifications, the interpretation of mining requirements into terms of machines and acting as design consultant on mechanical engineering problems within the Board's scope. Salary will be according to qualifications but will be not less than £2250.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/875. Original testimonials should not be forwarded. Closing date 18th December, 1954. E6703

SOUTH WEST METROPOLITAN REGIONAL HOSPITAL BOARD

SENIOR ASSISTANT ENGINEER (MECHANICAL)

Applications are invited for an appointment in this grade for a period of not less than two years. Salary grade £875 p.a., rising to £1025 p.a., plus London Weighting.

Applicants should be Corporate Members of the Institution of Mechanical Engineers and should be experienced in the preparation of specifications drawings and estimates for large steam boiler plants and mains.

Applications, stating age, experience, qualifications and the names and addresses of three referees, to be sent to the Secretary (S.2), marking the envelope "Engineering Staff," 11a, Portland Place, London, W.1, not later than 9th December. E6706

PUBLIC APPOINTMENTS

WAR DEPARTMENT

EGYPT

SHIFT ENGINEERS (ELECTRICAL AND MECHANICAL)

Applications invited from SHIFT ENGINEERS (Electrical and Mechanical) for service in Egypt. Candidates should have Ordinary National Certificate in Electrical or Mechanical Engineering or evidence of an equivalent standard of technical education, five years' apprenticeship or its equivalent with an engineering concern giving comprehensive training, at least three years' experience in operation of H.T. and L.T.A.C. power station electrical plant and switchgear and be able to supervise native switchboard attendants, or at least three years' sound training and experience in control and operation of modern medium-sized diesel-electrical generating plant and auxiliary equipment, and able to supervise native engine drivers. Appointment is for two years in first instance (one or two years in the case of electrical engineers) with possibility of extension and candidates must be prepared to complete tour unaccompanied by families. Starting pay will be fixed according to age, qualifications and experience on a range of £540 to £670. Foreign service allowance up to £458 a year, according to individual circumstances, may be payable in addition. Both salary and F.S.A. at present free from United Kingdom income tax (Schedule E) ; War Department accommodation provided free ; kit allowance of £35.—Candidates, who must be British and of British parentage, should apply to an Employment Exchange, quoting O.M.P. 809/54 or O.M.P. 809/2/54. E6725

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

RISLEY

ENGINEER GRADE I

ENGINEERS GRADE II AND GRADE III

United Kingdom Atomic Energy Authority at Risley requires an ENGINEER, Grade I (Ref. 742), to be responsible for a small specialist staff, and ENGINEERS Grade II and Grade III (Ref. 743), for work on major calculations required by design offices concerned with nuclear reactors and factories for producing fissile material. Subjects dealt with relate to fluid flow, heat transfer, nuclear radiation shielding and stress analysis. Qualifications : recognised engineering apprenticeship and Corporate Membership of a Senior Engineering Institution, together with similar experience to duties noted. Candidates for the Grade I post should have had extensive engineering experience, and an Honours Degree in Engineering would be desirable. Salaries assessed according to qualifications, experience and age as follows : Grade I, £1295–£1476 ; Grade II, £960–£1240 ; Grade III, £620 (at age 25) to £960. The successful candidates will later be required to join the Authority's contributory pensions scheme, and salaries will be increased to cover the contributions.

Applications to United Kingdom Atomic Energy Authority, Industrial Group Headquarters, P.O. Box 19, Risley, Warrington, quoting reference of post applied for. E6776

BRITISH ELECTRICITY AUTHORITY

EASTERN DIVISION

ASSISTANT ENGINEERS (MECHANICAL)

Applications are invited for the following positions in the Generation Construction Department at Divisional Headquarters in North London :—

SECOND ASSISTANT ENGINEER (MECHANICAL)

Salary, Class AX/DX, Grade 2, £834–£1053 per annum, plus London weighting.

THIRD ASSISTANT ENGINEER (MECHANICAL)

Salary, Class AX/DX, Grade 4, £763–£976 per annum, plus London weighting.

Applicants should have had experience in the design and installation of mechanical plant for generating stations and/or a knowledge of boiler or steam turbine design.

Applications, stating age, qualifications and experience, should be sent to the Controller, British Electricity Authority, Eastern Division, Northmet House, Southgate, N.14, to arrive by 4th December, 1954.

W. N. C. CLINCH,
E6737 Controller.

ASSISTANT ENGINEERS (CIVIL)

LONDON OFFICE

ASSISTANT ENGINEERS (CIVIL) required for their London Office by the Crown Agents for Oversea Governments and Administrations. Basic salary scale £650 by £25 to £750 by £30 to £960 by £40 to £1000 plus extra duty allowance of approximately 8 per cent. The £650 minimum is linked to entry at age 25 and is subject to increase at the rate of one increment for each year above that age up to 34. Fully qualified officers at least 27 years old, may be eligible for a special increase of £75 after two years' service. Engagement on unestablished terms with prospect of appointment to the established staff after five years' service and of promotion. Candidates must be Corporate Members of either the Institution of Civil Engineers or the Institution of Structural Engineers ; or, if below the age of 26, must have passed the Associate Membership Examination of either of these Institutions or hold an exempting degree. They must be good draughtsmen and should have had experience in the design and detailing of steel bridges and other steel structures, and should have served in the drawing-office of a structural firm, railway company or consulting engineers.

Write to the Crown Agents, 4, Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience, and quote M2A/30245/EH. E6781

PUBLIC APPOINTMENTS

PORT OF LONDON AUTH

HEAD OFFICE

DRAUGHTSMEN

The Port of London Authority invite ... for positions as DRAUGHTSMEN at ... Office. Commencing salaries will be ... the appropriate scale according to qualifi... experience. Increments are annual.

1. FIRST-CLASS DRAUGHTSMEN (C...
Salary scale : £627 10s. per annum by ... £758 15s. per annum.
Requirements : ability to design and de... variety of structures and buildings in ... concrete, steel and timber, and work with... supervision.

2. SECOND-CLASS DRAUGHTSMEN.
Salary scale : £552 per annum by £23... £596 per annum.
(a) Civil.
Requirements : ability to detail struc... buildings in reinforced concrete, steel ... with the minimum supervision, and ... designs. Experience in making site surveys ... an advantage.
(b) Survey and general duties.
Requirements : ability to carry out ... building surveys and plot the results, ... out general draughtsman's duties.

3. THIRD-CLASS DRAUGHTSMEN.
Salary scale : £425 10s. per annum by ... £23 to £506 per annum.
(a) Civil.
Requirements : ability to detail build... 2(a) above, under supervision. Experience ... site surveys would be an advantage.
(b) Survey.
Requirements : ability to survey land ... under supervision.

Application forms may be obtained ... Establishment Officer, Port of London ... Trinity Square, London, E.C.3.

BRITISH ELECTRICITY AUTH

NORTH EASTERN DIVISI...

POWER PLANT INVESTIGA...

The British Electricity Authority, No... Division, offers an opportunity for a man ... neering or other suitable qualifications ... investigational work in the metallurgical ... steam power plant maintenance. The ... will be made to the Divisional Headquarters ... Newcastle and will involve work in ... stations in the North East.

The salary for the appointment (whi... annuable) will be in accordance with ... Schedule "C," of the National Joint Bo... ment (£750–£925 per annum), and will ... at a point commensurate with qualifi... experience.

Forms of application may be obt... Divisional Establishments Officer, British ... Authority, North Eastern Division, Carl... Newcastle upon Tyne, 1, to whom they ... returned to arrive not later than 20th Dec...

SOUTH EASTERN GAS BO...

ELECTRICAL ENGINEER'S DEPA...
(AT FAIRFIELD STREET, WAND... S.W.18)

TECHNICAL ASSISTANT...

Applicants should be at least Gradu... Institution of Electrical Engineers, or ... qualifications which will lead to Corporate ... ship.

They must be familiar with the installa... tion and theory of A.C. and D.C. gener... transformers, switchgear, mercury arc re... and D.C. motors and cable systems.

They must be able to design electric... lighting installations, and to prepare detail... tions, drawings and diagrams relating th...

They will also be required to make ... inspections of electrical equipment in ... works, attend tests at manufacturers' w... reports thereon.

The salary will be not less than £820 ...

Applications received in response to ... published in August last will be con... re-application is not necessary.

Applications in writing, quoting refere... and giving full details, should reach the ... not later than fourteen days after the pu... this notice.

R. J. McCL...
Personnel ...

Katharine Street,
Croydon.

BRITISH ELECTRICITY AUT...

SOUTHERN DIVISION

ASSISTANT CHEMIST (METALL...

Applications are invited for the follow... ASSISTANT CHEMIST (METALL... Divisional Headquarters, Portsmouth ...

Applicants should be analytical chemi... experience in the analysis of ferrous and ... metals. Experience in the preparati... sections and interpretation of structure ... advantage.

Candidates should possess at least ... National Certificate or its equivalent, ... ship of the Institute of Metallurgists ... advantage.

Salary, N.J.B. AX/CX, Grade 6 (... £600 by £25 to £725 by £40 to £765.

Special application forms, obtainable ... Divisional Secretary, P. D. A. Oliver, ... Street, Portsmouth, should be returned ... 1st, 1955. Please quote reference E.

THE ENGINEER

NOVEMBER 26, 1954

"Comet" Court of Inquiry

ON Wednesday of last week, the submission of evidence in the "Comet" Court of Inquiry was concluded. Mr. A. L. Cripps, for the Ministry of Supply, referred to the co-operation between the Royal Aircraft Establishment and the de Havilland Aircraft Company and stated that if as late as June last, the R.A.E. was still not looking for fatigue as the primary cause of failure, that fact illustrated the state of existing knowledge at that time of the matter of fatigue. It was never thought that the "Comet" could still lead the world by incorporating the structural lessons this and other investigations had initiated. Mr. H. Povey, the manufacturer's production director, continued to submit further details of the company's inspection policy and department, which, he said, were adequate and capable. In the light of the investigation, however, the company would have to take a different view of many things in the future. On Monday the subjects of cracks was again the point of discussion. Lord Cohen, the commissioner, stated that whether or not the disasters originated from the manufacturing cracks disclosed in the evidence, it was now commonly admitted that such cracks could not be tolerated in highly stressed areas. Sir Hartley Shawcross said that in the future stress tolerances would be observed, which would prevent dangerous stresses arising as a result of cracks occurring. He submitted that three cracks and a few rivets out of place were the only errors of workmanship found following a microscopic examination of the aircraft, which were fabricated from over a million parts. The four mistakes, he maintained, had had no deleterious effect on the aircraft as a whole and they did not justify the sensational criticism made in some quarters.

Supervisory Equipment for Steam Turbine Shafts

PROBLEMS associated with shaft distortion and rotor movements in steam turbines formed the subject of two papers presented at a joint meeting of the Institution of Electrical Engineers and the Institution of Mechanical Engineers in London on Wednesday, November 24th. In the first paper Messrs. D. Antrich, H. W. B. Gardiner and R. K. Hilton described supervisory equipment, developed in the research laboratories of The General Electric Company, Ltd., for the indication of shaft distortion in steam turbines. This equipment consists, essentially, of a system of electromagnetic coils for detecting temporary shaft displacements, together with means for continuously indicating and recording the following four quantities: vertical eccentricity and horizontal eccentricity at the end of the shaft; differential axial movement of the end of the shaft relatively to the turbine casing; and rotational speed of the shaft. Indication is also given of the mean position of the shaft journal in relation to the bearing and its oil film, both horizontally and vertically. An auxiliary instrument, intended for occasional use during special investigations, is arranged to give an enlarged-scale display on a cathode-ray-oscillograph screen, of a polar diagram reproducing the motion of the shaft end. The paper gave details of operating experience derived from supervisory equipment of this kind fitted to the 60MW two-casing turbo-alternator sets at the B.E.A.'s Uskmouth power station. In the other I.E.E. paper Messrs. J. L. Ashworth, J. S. Hall, and A. H. Gray dealt with "the electrical measurement of steam turbine rotor movements, with special reference to the operation and design of modern power plant." The authors described "turbovisory" equipment developed by Metropolitan-Vickers Electrical Company, Ltd., for presenting to the turbine operator a continuous record of the behaviour of the rotor throughout the period of starting up and running on load. Practical experience on the measurement of differential axial expansion and shaft eccentricity, with about sixty equipments, some of which have been in service for nine years, was discussed in some detail. The authors then outlined some of the ways in which "turbovisory" readings could be used as aids to the operator and to the designer. Finally developments were described whereby future equipments of this class made provision for measurements of additional quantities, including speed and kilowatt output, differential temperatures between steam and metal, overall expansion, vibration and valve positions.

Graduates in Industry

THE Federation of British Industries has published this week two booklets on the subject of graduates in industry. The first of them, which is entitled *A Career for the Graduate in Industry*, is addressed to undergraduates and is being distributed to universities and schools, its aim being to emphasise that there are many satisfying careers in industry for both science and arts graduates. The booklet estimates that about 20 per cent of the staff posts in industry could be suitably filled by graduates, or could be considered as open to graduate competition. There are some notes on the prospects in industry of both science and arts graduates and a chapter which stresses the value of the university mind in industry. The second booklet, entitled *Industry and the Graduate*, is being sent to all the F.B.I. member-firms and its affiliated trade organisations. It points out that in the long term there can be no greater contribution to increased industrial efficiency than the recruitment of young men with qualities of leadership who can develop into good managers, and that with the increasing complexity and technicality of industry the demands on its leaders are more exacting than they have ever been. The booklet says that with greatly increased numbers of boys going to the universities, instead of entering employment direct from school, a far greater proportion of the potential managerial talent can now only be found in the universities. It has been estimated that only 9 per cent of boys of eighteen reach the level of intelligence required of leaders in industry or elsewhere. That being so, the booklet suggests, there were in 1912 over 30,000 potential managers seeking employment direct from school, but in 1951 there were only 11,000, the remainder, and presumably the best, being only available to industry after graduation.

Ministry of Transport Marine Survey Service

THE Ministry of Transport and Civil Aviation has announced that Mr. F. J. Colvill, C.B.E., Engineer Surveyor-in-Chief of the Marine Survey Service, is to retire on February 11th next. Mr. Colvill joined the Ministry as an engineer and ship surveyor in 1919, and served at Glasgow until 1923. He was promoted senior engineer surveyor in 1937. During the war Mr. Colvill was seconded to the Admiralty, where he served as Assistant Director of Merchant Shipbuilding (Machinery). He returned to the Ministry of Transport in 1946 and was appointed Deputy Engineer Surveyor-in-Chief a year later, becoming Engineer Surveyor-in-Chief in 1950. He was made a C.B.E. in this year's Birthday Honours. Mr. Colvill is to be succeeded by Mr. F. J. Welch, who has been Deputy Engineer Surveyor-in-Chief since 1950. He has been in the department since 1927. Captain J. C. Taylor, C.B.E., professional officer (chief nautical surveyor) of the Marine Survey Service, is retiring at his own request at the end of March, 1955. He will be succeeded by Captain J. H. Quick, who has been the principal examiner of masters and mates since 1945.

Mechanical Engineering as a Profession

THE Institution of Mechanical Engineers is arranging an afternoon conference, on Tuesday, December 7th, for headmasters and careers masters of public and grammar schools, to discuss recruitment to the profession of mechanical engineering. The conference will be held at the Institution's headquarters at 1, Birdcage Walk, Westminster, London, S.W.1, beginning at 3.30 p.m. Sir Ewart Smith, a vice-president of the Institution, and chairman of its education committee, is to preside, and other speakers will be Mr. T. A. Crowe, chief managing director of North British Locomotive Company, Ltd., and Major-General S. W. Joslin, C.B., of the United Kingdom Atomic Energy Authority. In announcing this conference, the Institution points out that, by virtue of its Royal Charter, it is particularly concerned with education and training at a professional level. With the post-war expansion of the engineering industry, the demand for mechanical engineers has been unsatisfied. The Institution is convinced that, in the interests of the country generally, public and grammar schools should have a full appreciation of the opportunities in the profession so that masters may be the better able to advise boys whose interests lean towards engineering. At 6.45 p.m. in the evening of the same day, December 7th, the education group of the Institution is to hold a discussion meeting to which those who attend the afternoon conference are invited. At that meeting the subject of "Recruitment from Secondary Grammar Schools" will be introduced by Professor S. J. Davies, D.Sc.

Interim Road Improvement Schemes in London

A NUMBER of questions about the inadequacy of the roads were put to Mr. Boyd Carpenter, the Minister of Transport and Civil Aviation, in the House of Commons on November 17th. The Minister said that he was very much aware of the traffic congestion in our large cities and towns, and was giving full weight to this consideration in allocating funds at his disposal for road works; he regarded the London traffic problem as of immediate urgency. His immediate task, he continued, was to put into effect a number of interim measures; these we briefly outline hereunder. The Cromwell Road extension scheme, at a cost of £3,000,000 from the Exchequer, will start in the next two or three months. The recommencement of the Dartford-Purfleet tunnel (£9,000,000 from the Exchequer) will be authorised in the early part of the next financial year. The first instalment of the new Route 11, planned by the City Corporation between Aldersgate Street and Moorgate, is hoped to be approved soon. A number of smaller road schemes include the widening of Piccadilly near Swallow Street and the widening of 1½ miles of the Great Cambridge road from the North Circular Road to Bury Street, Edmonton. Vehicle-actuated lights of a new kind are also proposed at various places, and route sign-posting in Central London is to be improved. The present "No Waiting" restrictions are to be substantially extended. Reports on proposed underground car parks at Grosvenor, Cavendish and Finsbury Squares are being examined, and other proposals concerning parking of cars and traffic flow are also being studied. These were preliminary measures, the Minister stated, and others would be announced when they were ready.

Thread Inserts

By B. CROSSLAND, M.Sc., Ph.D., A.M.I.Mech.E., A.F.R.Ae.S.

Some pull tests on thread inserts in two light alloys, carried out at the University of Bristol are here recorded. Incidentally the tests revealed that the conventional depth of insertion of mild steel studs is unnecessarily large.

HIGH-TENSILE steel thread inserts into light alloy were first produced commercially under the name of "Aero Threads," though the idea of thread inserts as such dates back much further. These inserts were helically wound from high-tensile steel or bronze spring wire and fitted in holes previously drilled and tapped in the light alloy. The thread in the light alloy was a normal vee thread, and the wire insert was formed so that it had the correct profile to fit this thread. The profile of the part of the wire insert which mated with the stud was semicircular and this fitted a thread of similar profile cut on the stud. This form of thread insert is shown in Fig. 1.

The advantages claimed for the Aero Thread are, first, that the fatigue resistance of the stud is improved, as there is no appreciable notch effect such as that given by a normal vee thread. Secondly, the stud or

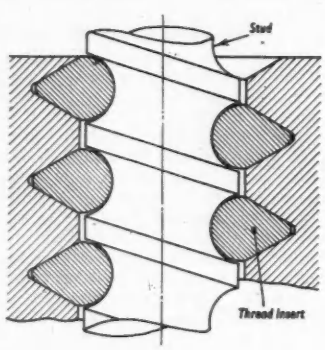


Fig. 1—"Aero" thread insert

set screw can be removed without damaging the light alloy, as the thread insert fully protects the soft threads in the tapped hole in the light alloy. A disadvantage of this form of insert is in the maintenance of sufficiently good tolerances in the manufacture of the stud and insert.

Within the past few years high-tensile steel wire inserts have been produced by the Cross Manufacturing Company, Ltd., of Bath. These inserts are designed to fit a stud having a normal thread profile as shown in Fig. 2. Very good accuracy in profile and dimensions is obtained by a hot rolling process, and these inserts have been approved by the A.I.D. The range of inserts so far produced is from 4 B.A. up to 7in diameter, though there is no difficulty in producing even larger sizes; they are available for nearly all the threads commonly used in this country.

A few samples of these inserts were submitted to the University of Bristol by the Cross Manufacturing Company, Ltd., for test, and the results appeared to be of sufficient interest to warrant further tests, particularly in view of the small amount of information available on this topic.

The practical engineer has adopted various empirical figures for the depth of insertion of mild steel studs into various metals, such as 2D for aluminium, 1½D for cast iron, bronze and brass, and 1D for steel, though these figures have little or no experimental backing. For high-tensile studs there seems to be no generally accepted figure, though the British Standard 1171 recommends that the depth of insertion into aluminium should be 2D. There is no information available on the strength of thread inserts.

Tests

For the pull tests two studs were screwed the required depth into inserts at either end of a tapped hole through a block of the material under test. These studs were enlarged at the nut end to ¾in B.S.F., so that they fitted into the axial loading shackles of a tension testing machine. The shackles are designed to ensure that the line of action of the load applied to the studs passes as nearly as possible through their axes. During the tests the load was slowly raised until failure occurred. Tension, compression and torsion tests were also carried out on the two light alloys used, to find the tensile and shear properties. With the tension tests axial loading shackles were used, and special torsion grips were employed to ensure that only a pure couple was applied to the torsion specimens. From the torsion tests it was hoped that the shear stress at failure could be deduced.

For these tests the studs were made from a high-tensile steel having an ultimate strength of 68 tons per square inch; the two light alloys were an aluminium to specification B.S.6.L1 and a zirconium magnesium such as that used in the aircraft industry. The zirconium magnesium was supplied by the Bristol Aeroplane Company and was to its specification BACE 239. Most of the tests were with studs having ¾in UNF and UNC threads, though a few tests were also carried out on ½in and $\frac{5}{16}$in UNF and UNC threads.

Results and Discussion

Tension Tests.—Two specimens of each material were tested with the results given below:—

Aluminium: ultimate strength 31·6 tons

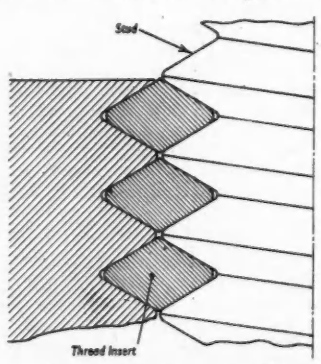


Fig. 2—"Cross" thread insert

and 32·5 tons per square inch, giving an average of 32·1 tons per square inch.

Zirconium magnesium: ultimate strength 7·70 tons and 7·82 tons per square inch, giving an average of 7·76 tons per square inch.

The aluminium specimens gave a normal ductile fracture with an appreciable reduction of area, whereas the zirconium magnesium gave a typical brittle fracture with a smaller reduction of area.

Torsion Test.—Three specimens of each material were tested to failure, the torque and the strain in the gauge length being measured throughout the test. The torque strain curves were drawn and the shear stress was deduced by the method suggested by Nadai (*Theory of Flow and Fracture of Solids*, Vol. I, published by McGraw-Hill), so that the shear stress at failure could be deter-

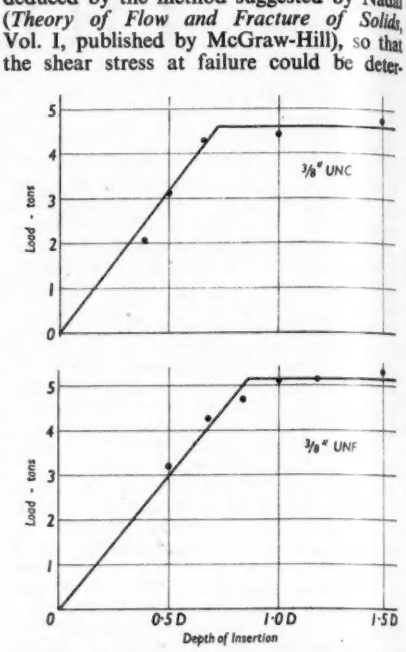


Fig. 3—Variation of pull strength with depth of insertion

mined. This gave an ultimate shear stress for aluminium of 17·2 tons per square inch and a shear stress at failure for the zirconium magnesium of 6·3 tons per square inch.

The aluminium specimens failed in a plane transverse to the axis of the specimen (i.e. typical shear fracture), but the zirconium magnesium failed on a helical plane inclined at 45 deg. to the axis of the specimen, which shows that the specimen had failed due to the tensile component of the shear stress. Consequently the shear stress at failure for the zirconium magnesium torsion

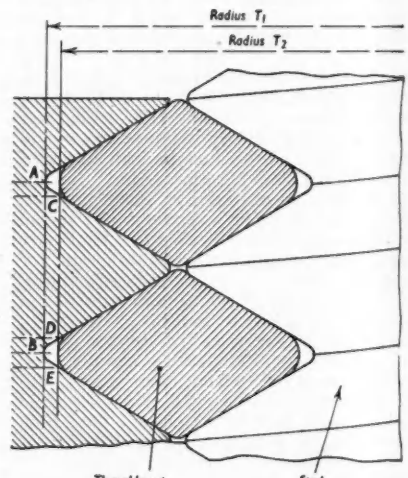


Fig. 4—Detail of "Cross" thread insert

specimen is not necessarily the ultimate shear stress for the material, and it may well be that the ultimate is much higher than the figure of 6·3 tons per square inch.

Compression Tests on Zirconium Magnesium.—It was considered that the ultimate shear stress could be found from a compression test, as failure of a brittle material in compression mostly occurs along the plane of maximum shear. Two compression

specimens were tested between hardened steel plates, the ends of the specimens being lubricated throughout the test with calcium oleate to prevent "barrelling." Both tests gave identical results and failure in both cases was approximately at 45 deg. to the axis of the specimen (i.e. plane of maximum shear). The derived value of the ultimate shear stress on the plane of failure was 7·65 tons per square inch (i.e. half the compressive stress at the instant failure took place).

Pull Tests

The results of the pull tests carried out are given in Table I and the results of the tests on ½in UNC and UNF studs in aluminium are shown plotted in Fig. 3.

Three distinct forms of failure were noted in these tests, one, a tension failure of the stud, the second, the thread insert pulling out of the light alloy by shearing through the threads in the light alloy and, the last, a tension failure in the light alloy. In Table I the ultimate strength of the studs which failed (based on the core area) has been given, and it will be noted that the figures are fairly consistent. When failure was due to shearing of the threads the nominal shear stress based on the diameter of the thread in the light alloy has been calculated and this figure is given in Table I. This assumes that shearing takes place on an area equal to the product of the diameter of the thread in the light alloy and the depth of insertion. The diameters of the threads in the light alloy to take the thread inserts are given in Table II.

Table I—*Results of Pull Tests on Thread Inserts*

Thread	Material	Depth of stud insertion	Load at failure	Form of failure	Nominal shear stress at failure	Stress in stud at failure	Nominal shear stress in light alloy ÷ Ultimate shear stress
			Tons		Tons/in²	Tons/in²	
½in UNF	Aluminium	1·5D	5·19	1	—	63	—
½in UNF	Aluminium	1·166D	5·13	1	—	62·2	—
½in UNF	Aluminium	1D	5·06	2	10·2	—	0·595
½in UNF	Aluminium	0·833D	4·78	2	11·6	—	0·675
½in UNF	Aluminium	0·666D	4·15	2	12·6	—	0·73
½in UNF	Aluminium	0·500D	3·14	2	12·6	—	0·73
½in UNC	Aluminium	1·5D	4·68	1	—	66·9	—
½in UNC	Aluminium	1D	4·42	1	—	63·1	—
½in UNC	Aluminium	0·666D	4·34	2	12·4	—	0·720
½in UNC	Aluminium	0·500D	3·10	2	11·9	—	0·690
½in UNC	Aluminium	0·333D	2·04	2	11·7	—	0·680
⅝in UNF	Aluminium	1·5D	3·42	1	—	63·6	—
⅝in UNF	Aluminium	0·666D	2·61	2	11·2	—	0·65
⅝in UNC	Aluminium	1·5D	3·08	1	—	65·6	—
⅝in UNC	Aluminium	0·533D	2·20	2	11·3	—	0·657
¾in UNF	Aluminium	1·5D	9·92	1	—	66	—
¾in UNF	Aluminium	0·7D	7·35	2	12·1	—	0·703
¾in UNC	Aluminium	1·5D	8·60	1	—	69·2	—
¾in UNC	Aluminium	0·615	7·17	2	12·6	—	0·73
¾in UNF	Zirconium magnesium	0·889D	2·47	2	5·6	—	0·73
¾in UNF	Zirconium magnesium	0·444D	1·23	3	(5·6)	—	(0·73)*
¾in UNC	Zirconium magnesium	1D	2·74	2	5·25	—	0·685
¾in UNC	Zirconium magnesium	0·5D	1·3	3	(5·00)	—	(0·655)*
⅞in UNF	Zirconium magnesium	1·6D	3·22	1	—	60	—
⅞in UNF	Zirconium magnesium	0·8D	1·54	2	5·5	—	0·718
⅞in UNC	Zirconium magnesium	1·245D	2·58	2	5·67	—	0·74
⅞in UNC	Zirconium magnesium	0·888D	1·85	2	5·70	—	0·745

D is diameter of stud. 1—Tension failure of stud. 2—Thread insert pulled out of light alloy. 3—Tension failure in light alloy
* Nominal shear stress given though failure was not caused by thread insert pulling out of light alloy.

Table II

Stud diameter	Maximum diameter of thread in light alloy	
	UNF	UNC
½in	0·3576in	0·3725in
⅝in	0·4201in	0·4427in
¾in	0·5541in	0·5833in

The last column in Table I gives the ratio of the nominal shear stress at failure of the insert to the ultimate shear stress determined from either a torsion or compression test; this might be regarded as the "shear efficiency of a thread." It will be seen that this ratio is reasonably constant within the limits of experimental and manufacturing errors. That the ratio is not unity is due to the tip clearance between the thread insert and the thread tapped in the light alloy, which reduces the effective area over which shear occurs. This is made clear in Fig. 4; the nominal shear stress given in Table I is worked out on an area equal to $2\pi r_1 \times$ depth of insertion, whereas shear actually occurs over an area of $2\pi r_2 \times CD/CE \times$ depth of insertion. From examination of the sheared threads the value of CD/CE is approximately ⅔, this would give a value of $r_2/r_1 \times CD/CE$ less than 0·75, which is in fair agreement with the experimental value given in the last column of Table I.

Two cases of a tension failure of the zirconium magnesium were noted. With this type of failure a shallow conical-shaped piece of the material was pulled out of the test block. This form of failure only occurs for small depths of insertion in brittle materials. In the two tensile failures experiences the shear ratio at the maximum load indicates that a shear failure might have equally well occurred.

It has been seen that the strength of the thread in the light alloy is closely related to the ultimate shear strength of the alloy, as might be expected. From examination of the values of the ultimate shear stress and the ultimate tensile strength it can be seen that the strength of the threads in the light alloy is not related to the tensile strength.

Conclusion

From the pull tests on high tensile steel studs screwed into thread inserts in aluminium it can be concluded that a depth of insertion of one diameter is more than sufficient. With this depth of insertion the stud will fail before the thread in the aluminium is sheared. For a zirconium magnesium, which is a very weak and brittle material, the depth of insertion need not exceed 1·75D. If the studs had been screwed straight into the light alloys with no thread insert, then the above figures would have to be increased by about 20 per cent, as the diameter of the thread in the light alloy would be reduced.

The tests clearly demonstrate that for a failure in which the stud and thread insert is pulled out, shearing the threads in the light alloy, the strength is dependent on the shear strength of the material into which the insert is screwed. This would obviously also apply to the case of a stud used without an insert.

The pull strength of a stud can be readily estimated if the ultimate shear stress of the material is known. The strength will be given by: $\pi d \times$ depth of insertion $\times$ shear eff. of the thread $\times$ ultimate shear stress. where d is the diameter of the thread in the material into which the stud or thread insert is screwed. The shear efficiency of the thread is the ratio of the nominal shear stress acting on the thread at failure to the ultimate shear stress of the material, and it had a value of 0·65 for the threads tested. This shear efficiency will vary with the tolerances on the threads, but the above value may be taken as a fairly average figure. If the load thus calculated is greater than the ultimate strength of the stud calculated on its core diameter, then failure of the stud will occur before the threads are sheared.

The tests carried out showed that the normally accepted figures for the depth of insertion of mild steel studs must be far in excess of those strictly necessary.

Agricultural Machinery Manufacturing Development

On Thursday of last week we were invited to the Ipswich works of Ransomes, Sims and Jefferies, Ltd., to see a display of the agricultural machinery and implements which that firm manufactures, and to hear some details of a further stage in manufacturing and marketing arrangements which has been agreed with the Ford Motor Company, Ltd., Dagenham, Essex. The original arrangement between the two companies was made nine years ago, when the "blending" of various implements to a tractor had started, but was by no means an accepted principle of farm mechanisation.

The decision then reached related to a pooling of the design and manufacturing resources of Ransomes, Sims and Jefferies, Ltd., and the Ford Motor Company, Ltd., for the development and production of a number of basic mounted implements, such as ploughs, tool bars and disc harrows for operation on the three-point linkage of the Fordson "Major" tractor. These products, known as "F-R" implements, have been made available to the home market through the dealer organisation of both companies, the overseas sales being dealt with by the Ford export organisation. For a start the "F-R" implements were built at the Ford Company's Leamington factory, but more recently production of these implements has also been undertaken at Ipswich. It has now been decided that, from January 1st next, the production of all the "F-R" implements shall be concentrated at Ipswich, and to that end Ransomes, Sims and Jefferies, Ltd., has built a new factory which is nearing completion at Nacton, on a site adjacent to its foundry, and which will double the area of the present manufacturing facilities. In the home market, these products, as well as the farm machinery and implements manufactured exclusively by Ransomes, are to be distributed by the dealer services of both companies. Overseas, the "F-R" products will be dealt with by the Ford export organisation, which will also handle Ransomes' farm machinery and implements under the name "F-R Nacton." This arrangement is additional to the existing activities of Ransomes' overseas marketing organisation.

At the display last week, several new implements were on view. They included a three-furrow reversible disc plough; several tool bars for cultivators, hoes, ridgers and beet lifters, and a mounted disc harrow. Following the machinery display, the visitors were entertained to a luncheon, at which the new arrangements were outlined by Mr. W. D. Akester, of Ransomes, Sims and Jefferies, Ltd., and Mr. F. W. Daniels, of Ford Motor Company, Ltd.

Slotted Angle System.—A new kind of slotted angle, for light or temporary structures, such as racks and shelves, is now being marketed by Chevron Structural Units, Ltd., 7, Victoria Street, London, S.W.1. The angles are 2in by 2in or 3in by 2in in size, with corrosion-resistant finish. V-shaped slots are cut in each leg of the angle. The slots are 1in long, measured between the ends of the "V," and are spaced 1in apart along the angle, so that they overlap, as a series of "Vs" and inverted "Vs." The particular merit claimed for the system is that, no matter in what position two angles are presented to each other, bolt holes are available, and there are no "blind spots," thus giving a considerable flexibility in assembling. The bolts used with the angles engage in the slots, so that the nut may be tightened with a single spanner.

Guided Missiles

By G. W. H. GARDNER, C.B.E.*

No. I

In the James Clayton lecture before the Institution of Mechanical Engineers last Friday, November 19th, extracts from which are here printed, Mr. Gardner took as an example the technical problems of designing a ground-to-air weapon. After defining its task, and the principles of guidance, he went on to consider the effects of kinematics and aerodynamic heating. On propulsion, he discussed the ram jet, the rocket motor and the turbo-jet. In conclusion he had something to say about "Tridac," the three-dimensional analogue computer installed at the Royal Aircraft Establishment.

Scope of Future Guided Missiles

AFTER the war, study of the German achievements resulted in an intensification of the attention already being paid throughout the world to the potentiality of new guided missile conceptions embodying up-to-date techniques, particularly radar. Such conceptions in the anti-aircraft role did not require visual sight of the target, nor the intervention of a human operator in order to guide the missiles.

It seemed possible not only to detect and track an aeroplane from the ground or from another aeroplane, but also for the missile to seek and track its target and to detonate its war-head in the proximity of the target. By this means the point of aim could be carried to the target and continuous aiming corrections could be made during the flight of the missile. It appeared that a wide range of electro-magnetic wavelengths could be exploited. The flexibility of anti-aircraft missiles could thereby be extended, as compared with the German weapons, by their use in all weather conditions by night or by day. Again it seemed possible to exploit detection of targets on the ground or at sea by radar or other means, and thereby to direct air, ground or ship-launched missiles against these targets. Advances in aerodynamics and propulsion offered the possibility of flight at high supersonic speeds for any missile in which this feature would improve its effectiveness. Improved knowledge of servo-mechanisms and automatic control systems promised the ability to use the positional intelligence, obtained electromagnetically, to direct and steer the missile to the vicinity of the target with sufficient accuracy to offer a good chance of causing damage.

These possibilities suggested a wide range of applications for attacking ships under or above the water line, for the purposes of air, ground or ship-launched anti-aircraft weapons, and for attacking land or sea targets from land, sea or air.

Some of the Problems

Some coherence can be given to a discussion of typical problems by confining attention to one of the many types of weapon, and the ground-to-air guided weapon has been selected for this purpose.

The Task of the Ground-to-Air Weapon.—The requirement for the ground-to-air weapon may be for the defence of vulnerable points, such as towns, factories and ports, or of large areas such as the whole of Britain. Attack may be launched at any height up to the maximum operating height of bombers within the next ten years (say, 60,000ft). Contemporary bombers fly at subsonic speeds, but we must expect to have to be prepared to contend with supersonic attack in ten years' time, say, at 1000 m.p.h., or nearly 17 miles per minute. Early warning by radar of the highest bombers is limited by the geometry of the system and this means a maximum warning time of about ten minutes before bomb release at 60,000ft, and progressively less at lower heights. During this time the strength, height and direction of the raid must be assessed, a decision made to select and put into action appropriate defence units (including the acquisition of the targets by the necessary ground-based radar control system) and to launch the missiles in time to permit them to intercept and destroy their targets.

This at once emphasises some of the advantages and disadvantages of the guided missile relative to the manned interceptor aircraft. The missile is not subject to the physiological limitations of the human pilot, nor does it have to return to base. It can be provided with ability to accelerate more violently and can therefore take off, climb

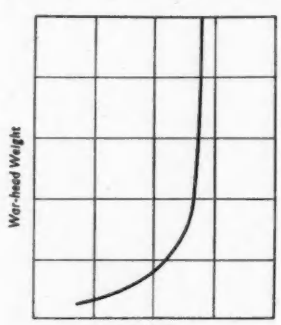


Fig. 1—Typical relation between war-head weight and miss distance

to height, and manœuvre into position for the final phase of interception in a much shorter time. It can be fired in any weather conditions. On the other hand, the manned interceptor retains the benefit of supervisory human judgment at all stages of its flight and the versatility of mobility over a wide front. The need for effective guided missiles becomes more acute if a raid by atomic bomb carriers is expected, as it will then be necessary to destroy the bomber at an earlier time, preferably well out to sea, and with a high degree of certainty.

War-head.—In designing a missile of this kind one must first decide the nature and size of the war-head. It can be designed to produce a blast effect or to radiate fragments at very high velocity. A few pounds of high explosive would be adequate if there were a high chance of a direct hit (Fig. 1). Since this is improbable it should instead carry sufficient high explosive (100 lb or 200 lb) to ensure lethal damage from a near miss when the war-head is detonated by a proximity fuse. If the miss were greater than about 100 yards a prohibitive amount of explosive would be required. Accordingly, one must arrange to guide the missile to within that distance of the target. This is no mean task, since the closing speed of target and missile may be about half a mile per second, and the target may be manœuvring.

Guidance.—A guidance system must be devised to achieve the required accuracy. One possible system provides for the missile to seek and home on the target (Fig. 2). This

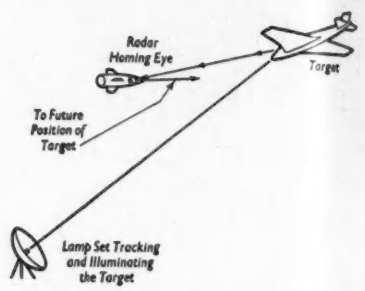


Fig. 2—Semi-active homing

can be done by illuminating the target with a radar beam transmitted by the missile (active homing) or by a source outside the missile (semi-active homing) and by fitting a seeker in the missile able to pick up and "look" towards the target which acts as the source of the reflected radar energy. A control system can then be devised to cause the missile to fly towards the target. But this system demands much complication within the missile.

A system which permits simpler missile equipment can be provided by continuous measurement by radar from the ground or ship of the positions of the target and the missile (Fig. 3). This information is fed into a computer which transmits, to the

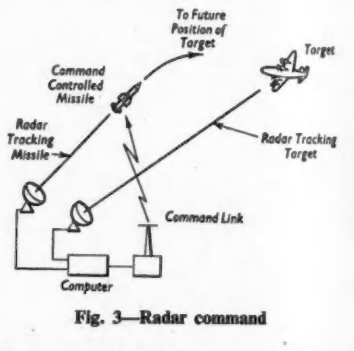


Fig. 3—Radar command

missile automatically by radio, commands in the form of steering instructions designed to ensure interception of the target,

Another method is to lock a narrow radar beam to the target and cause the missile to measure its own position in relation to the centre line of the beam and fly as close

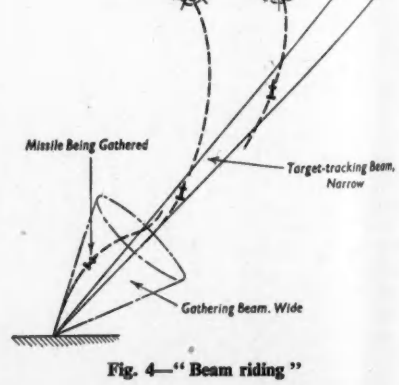


Fig. 4—"Beam riding"

* Director-General of Technical Development (Air), Ministry of Supply.

as possible to this line. This method is normally called " beam riding " (Fig. 4).

Kinematics and Aerodynamic Heating.—After the form of guidance has been decided, it is then necessary to consider the kinematics of the interception, the configuration and propulsion of the missile and, finally, to close the loop, the control system required to provide the necessary stability and manœuvrability.

The missile must fly at very high speed. The " sound barrier," which exists because of the sharp rise in drag in the region of the speed of sound, can be surmounted by designing for low drag and by providing adequate thrust per unit frontal area.

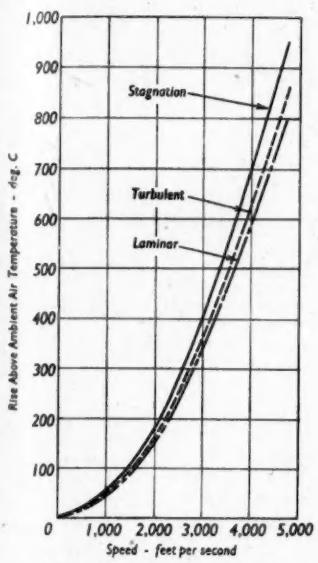
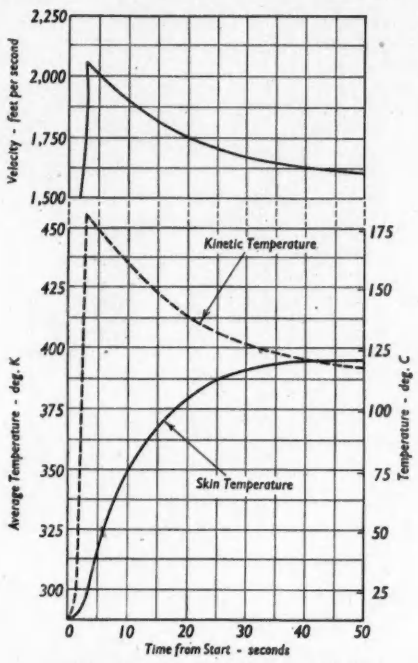


Fig. 5—Variation of air temperature rise above ambient with the speed of a body

Acceleration can thereby be ensured through the trans-sonic region to the higher speeds necessary to achieve the desired interception performance. The " thermal barrier," however, presents a problem which becomes progressively more severe as speed rises (Fig. 5). Air in the boundary layer (adjacent to the skin), which is accelerated to the speed of the missile is heated by friction and compressive forces, and the skin is thus heated by conduction. This phenomenon is known as aerodynamic heating. To a first approximation, the temperature rise in the stagnation regions of a body, in this instance due solely to compression of the air, can be expressed by the simple relation $\Delta T=(V/100)^2$, where ΔT is the temperature rise in degrees Centigrade and V is the true air speed in miles per hour. Thus it is seen that whilst, at 100 m.p.h., ΔT is only 1 deg. Cent., it is 400 deg. Cent. at 2000 m.p.h. The actual temperature rise experienced over most of the body is about $0{\cdot}85\Delta T$.

Lag effects play a prominent part during transient conditions. Fig. 6 depicts the temperature rise experienced by a fibreglass conical forebody over a period of fifty seconds. Clearly, if a missile or aeroplane is required to fly for more than a very short time at a speed much greater than twice the speed of sound, it will be necessary in the structure to avoid the use of aluminium alloys which lose strength and stiffness rapidly above 150 deg. Cent. and to use instead titanium alloys or possibly steel to withstand higher temperatures (Fig. 7). Some alleviation of this difficulty can be obtained by insulation of the structure by, for example, the use of a carboniferous insulating material having a high specific heat and also a high melting point. If to the aerodynamic heating effects are added temperature effects due to a rocket-motor combustion chamber and exit nozzle in which the flame temperature may be 2500 deg. K., and to a liquid oxygen supply which may cause the temperature of parts



Variation of average skin temperature with time. Material, fibreglass ; cone length, 4·33ft ; cone total angle, 20 deg. ; skin thickness, 0·040in ; boundary layer, laminar.

Fig. 6—Transient skin temperatures for a conical forebody in accelerated flight at sea level

of the missile to fall as low as 120 deg. K., the resultant engineering problems become truly formidable.

The range of the missile will emerge from geographical, economic and kinematic considerations. It is interesting to note that a given missile can achieve a greater range by

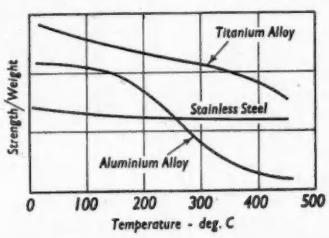


Fig. 7—Variation of strength with temperature for an aluminium alloy, a titanium alloy and a steel

following an indirect route to the target than by following a direct path. Fig. 8 shows that a typical rocket-propelled missile can travel two or three times as far by following indirect paths which minimise the time spent in the denser air at the lower heights. Choice of path is linked to choice of guidance ; for example, beam riding would not permit either of the indirect paths shown.

The manœuvrability required at different heights must next be determined, so that sufficient lifting surface or wing area and adequate effectiveness of control can be provided for the greater heights, and sufficient strength for the lower heights. It is readily seen that a simple pursuit-course interception, in which the missile at all times points straight towards the target, can demand accelerations which are impossible to provide (Fig. 9). The demand can be limited or even caused to vanish after a time by adopting some such arbitrary law as $d\psi/dt=kd\theta/dt$, where ψ is the direction in which the missile is pointing and θ is the angle of the line of sight to the target (Fig. 10). The constant k can be chosen to ensure that the path approximates to a constant-bearing collision course, and to reduce thereby the maximum acceleration demand. Acceleration capability must also be made to compete with any manœuvring of the target and with impurities on the

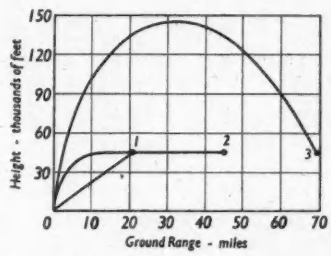
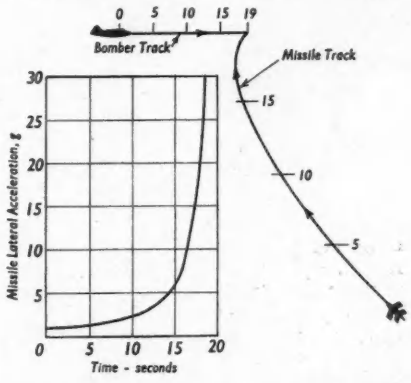


Fig. 8—Typical effects of trajectory on ground range

radar intelligence. All of these considerations together may demand the ability to manœuvre at between 10g and 20g.

With a knowledge of the war-head size, the speed, range, guidance method and control law, the propulsion system and aerodynamic form of the missile can be determined.

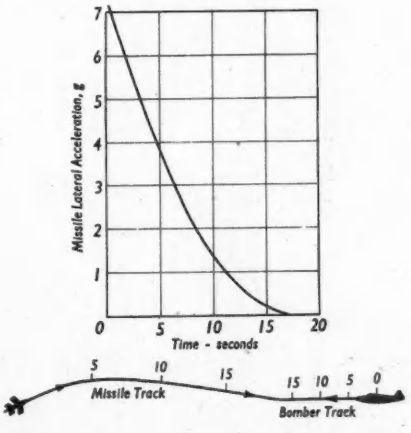
Propulsion.—Because missiles are required



Bomber speed, 800ft per sec., missile speed, 2000ft per sec. ; initial range, 45,000ft ; numbers on curves denote time in seconds.

Fig. 9—Pursuit course : missile against bomber

to fly at very high speeds, and because the horsepower required to propel the missile rises as the cube of the speed up to about $M=0{\cdot}8$, at a greater rate depending on the aerodynamic design up to about $M=1{\cdot}5$,



Bomber speed, 800ft per sec. ; missile speed, 2000ft per sec. ; initial range, 50,000ft ; proportional navigation constant $k=5$; numbers on curves denote time in seconds.

Fig. 10—Proportional navigation course : missile against bomber

and beyond that speed at rather more than the square of the speed, it is essential to seek an engine of very high thrust per unit frontal area, and of low specific weight and fuel consumption. A considerable excess of power must, of course, be provided to achieve very high acceleration. (*M*, the Mach number, is the ratio of the speed of the missile to the local speed of sound. The outstanding work on the flight of projectiles and the flow of gases by Professor Ernst Mach, some fifteen years before the Wright brothers first flew in 1903, merits the perpetuation of his name in supersonics, a field in which he was truly a pioneer.)

Jet reaction motors are most suitable and a choice of three types is available—the rocket, the turbo-jet and the ram jet. The rocket motor is independent of the surrounding atmosphere in that the source of the oxygen necessary for combustion is carried in the rocket in solid or liquid form. In contrast the turbo-jet engine and the ram jet draw their oxygen from the atmosphere.

Ram Jet.—The ram jet, whose use is confined to high-speed flight, is notable for its simplicity (Fig. 11). The motor itself contains no moving parts. The function

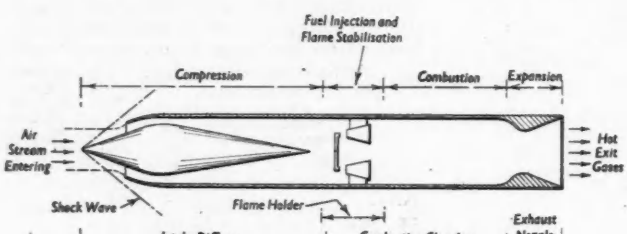


Fig. 11—Ram jet

of the compressor in a turbo-jet engine is to raise the pressure of the incoming air to a value which will ensure good thermal efficiency. If, however, the turbo-jet is flying at twice the speed of sound at sea level the total head or ram pressure at the intake is 115 lb per square inch absolute, which is equivalent to a compression ratio of 7·8/1, assuming 100 per cent intake efficiency. This process of compression by conversion of the high kinetic energy of the air usurps the functions of a mechanical compressor. If the compressor is dispensed

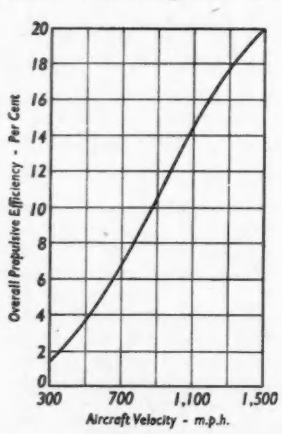


Fig. 12—Overall propulsive efficiency of ram jet plotted against aircraft velocity

with, it follows that no turbine is required and one arrives at the ram jet.

The ram jet is unable to provide thrust at zero speed and is so inefficient at low speeds that it must be boosted to a speed approaching that of its designed operation by other means (Fig. 12). For defensive missiles, this is not a handicap. Whatever propulsion motor is used, much more powerful boost motors giving thrust of the order of twenty to thirty times the weight of the missile are needed in addition in order to achieve an acceptable time from launching to operational speed.

Although the ram jet is simple, in the sense that it contains no moving parts, substantial aerodynamic, combustion and fuel supply problems must be solved to ensure efficient functioning over a wide range of height and speed.

The design of the air intake is a formidable problem. The air must be retarded, with minimum loss, from the flight speed to the internal flow speed at the entrance to the combustion region. At supersonic flight speed retardation can be caused by the creation at the intake entry of shock waves behind which the flow is subsonic, and thereafter a subsonic diffuser is used. At relatively low speeds, below $M=1\cdot5$, one shock is sufficient, but above this speed a series of shocks is required to obtain efficient compression.

It is important to ensure that the characteristics of the air intake match those of the ram-jet combustion chamber. The air-swallowing capacity of the intake and its ability to compress the air efficiently are a function not only of the operating condition of the combustion chamber but also of the flight speed. Speaking quite generally, it may be said that an air intake which matches the combustion chamber at a given speed will be too large at a lower speed, and this gives rise to air spillage around the intake, resulting in greatly increased drag and possible instability of flow, which in turn can have repercussions on the stability of combustion. This question of matching leads to perhaps one of the most difficult ram-jet design problems necessitating well-considered compromise. In practice, this compromise may be turned to good effect since the intake characteristics can be utilised to provide a major control of thrust. For higher speed flight and longer ranges where fuel economy is of greater importance, a variable intake will probably be required to provide optimum matching over the speed range, although this would detract from the inherent simplicity of the ram jet.

For a ram-jet-propelled missile of short range the overall weight is of great importance and it is preferable to save structure weight even at the expense of fuel economy. This fact, associated with the demand to get the greatest possible thrust from the ram jet, results in air-entry velocities to the combustion chamber of the order of between 200ft and 300ft per second. This, in turn, implies that the drag coefficient of the flame-stabilising system of the combustion chamber must be kept small and that, in consequence, the degree of mixing given to the fuel and air mixture and the combustion products is much less than that permitted in a combustion chamber of a gas turbine engine.

Furthermore, the intensity of heat release demanded of a ram-jet chamber (about 4×10^6 C.H.U. per cubic foot per hour per atmosphere) is greater than that required from turbine engines and the flow pattern of the entry air is also more susceptible to operating conditions. All these factors aggravate the difficulties associated with combustion. Moreover, the large interchange of kinetic, pressure and thermal energies can sometimes lead to vibrations of amplitude sufficient to cause severe damage. The general necessity to keep engines short in length does not mitigate these problems. Research and development programmes must be concentrated on obtaining combustion chambers which are reliable in the mechanical sense and capable of operating under a variety of air-flow conditions.

Usually increase in flight performance demands more complexity and reduced reliability of the many components of a high-speed missile or aeroplane. The ram jet is an exception in this trend. A ram jet capable of exerting, say, 100,000 h.p., can be built with less than a dozen moving parts and these are confined to the associated fuel supply and control systems. None of these moving parts is in contact with hot gases.

Rocket Motor.—The rocket motor is also simple in the sense that in the solid propellant version there are no moving parts at all, and in the liquid fuel version the only moving parts are associated, as in the ram jet, with fuel supply and control. Aerodynamic problems associated with air swallowing are absent and motors can be tested up to full thrust on the ground with less extravagant facilities. In addition, because of its independence of the surrounding atmosphere, thrust at altitude is maintained; in fact, it increases somewhat as the atmospheric pressure falls. Fig. 13 shows the variation of thrust of a rocket and turbo-jet engine with altitude. The chemical problems associated with rocket propulsion are, however, more acute and because the specific fuel consumption of rockets is many times greater than that of air-swallowing engines, great endeavour is made to employ higher flame temperatures to reduce this deficiency. Flame temperatures commonly

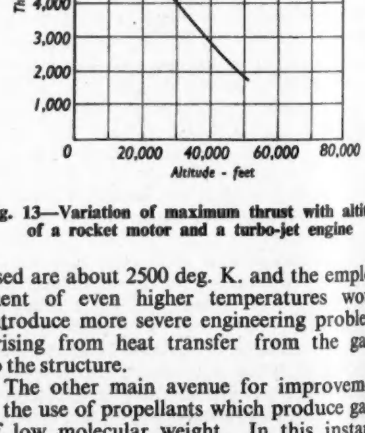


Fig. 13—Variation of maximum thrust with altitude of a rocket motor and a turbo-jet engine

used are about 2500 deg. K. and the employment of even higher temperatures would introduce more severe engineering problems arising from heat transfer from the gases to the structure.

The other main avenue for improvement is the use of propellants which produce gases of low molecular weight. In this instance the performance is inversely proportional to the square root of the molecular weight. Fuels now available can be pressed, extruded or cast in the solid form. Liquid hydrocarbon fuels in association with highly concentrated hydrogen peroxide, liquid oxygen or nitric acid, are also used. Work on rocket motors has led to some most interesting mechanical developments. The

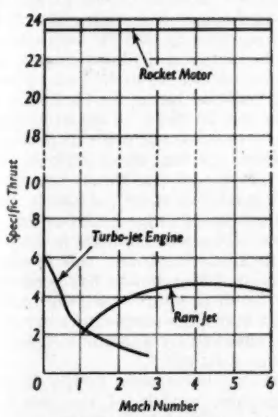
development of the high-speed fuel pump and its associated bearings and seals due to Barske and recently described in THE ENGINEER* are worthy of special note. Another notable development is the successful welding and heat-treatment of thin high-tensile-steel sheets in cylindrical form to provide casings for solid propellant motors. Cylinders of 70-ton steel, 0·063in thick, have been made in this way to withstand a pressure of 1500 lb per square inch.

Table I indicates, by comparison with examples of engines of other types, the enormous thrust horsepower achievable with the rocket motor for an extremely low weight. The "V.2" liquid fuel motor was remarkable in giving a thrust of 69,000 lb for a dry weight of only 2235 lb complete. The speed reached by the missile after about sixty seconds, when the motor had completed its task, was approximately 5000ft per second (M=5·2). The engines are listed in Table I

TABLE I—*Some Performance Figures for Various Engines*

Engine	Thrust horsepower	Specific power, thrust h.p. per lb weight of engine	Overhaul period	Distance travelled, nautical miles
"V.2" liquid-fuel rocket	627,000 (at M=5·2)	281·0	60 seconds	13
Aircraft turbo-jet: Present ...	8,700 (at M=0·9)	3·5	600 hours	240,000
Future	35,000 (at M=1·5)	9·5	600 hours	500,000
Aircraft piston	1,080	0·54	600 hours	180,000
4-6-2 steam locomotive	1,800	0·009	18 months	130,000
Modern geared steam turbine (marine)	9,100	0·008	1 year	122,500
Geared steam turbine (R.M.S. "Queen Mary")	104,000	0·0035	1 year	202,000

in order of specific power and, while it is, of course, unfair, in view of the diverse duties and operating speeds of the vehicles which these engines propel, to compare performances from this aspect only, some interesting, if incidental, arguments can nevertheless



Specific thrust=(net thrust at cruising altitude)/(engine dry weight).

Fig. 14—Specific thrust of rocket motor, turbo-jet engine and ram jet at cruising altitude

be developed. For example, the very high specific power of the rocket is consistent with its very short designed life. On the other hand, the overhaul period of the aircraft turbo-jet engine is only 600 hours by comparison with a year (equivalent to about 7200 hours' operation) for the geared steam turbine (marine) engine (which again might explain their relative specific powers), but further examination reveals that whereas the aircraft engine might easily have covered 240,000 nautical miles, the ship engine installed in, say, a fast cargo boat would have covered perhaps only half this distance.

*April 17th, 1953, page 550

Turbo-jet Engine.—In the past ten years the thrust per unit area of British turbo-jet engines has been increased six times, their specific weight has been halved and their specific fuel consumption reduced by 20 per cent. Nevertheless, the turbo-jet does not yet compete with the rocket or ram jet as a means of propelling relatively short-range, defensive missiles. We shall see better where it fits by examination of Figs. 14, 15 and 16.

Choice of Propulsion Method.—Fig. 14 shows the outstanding merit of the rocket motor in terms of thrust divided by weight at

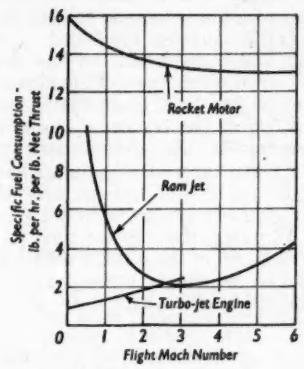


Fig. 15—Specific fuel consumption of rocket motor, ram jet and turbo-jet engine at cruising altitude

all speeds by comparison with the turbo-jet engine and ram jet.

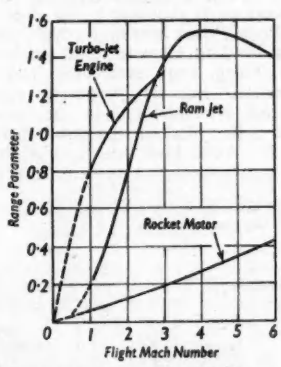
Fig. 15 shows the penalty in terms of fuel consumption of using a rocket motor and shows the superiority of the ram jet at speeds greater than M=2·5.

Fig. 16 shows the range superiority of the turbo-jet engine at moderate speeds and of the ram jet at the highest speeds.

In calculating the points on the curves just described, an arbitrary relation between speed and height has been adopted. M=2 is assumed to occur at 60,000ft, and M=4 at 80,000ft.

It is clear that the rocket motor is most suitable for use as the boost to give an acceleration of, say, 25g, for, say, two seconds, and to achieve a speed of about one-and-a-half times the speed of sound.

It is efficient to discard the boost-motor carcase after the fuel is burnt, thereby reducing the weight and drag of the missile



For a given ratio of initial to final weight and of lift to drag, range is proportional to the range parameter. At subsonic speeds lift/drag ratios are about three times those at supersonic speeds.

Fig. 16—Range parameter plotted against speed

and a solid fuel system fits this requirement most conveniently.

It is found that the weight of the boost motors is of the same order as that of the missile, and since it is important to keep this weight as low as possible, great attention must be paid to the choice of propellant on the one hand and, on the other, to the reduction of deadweight consisting of the metal container, the nozzle, stabilising fins and other fittings. Work on methods of manufacture of very thin-walled tubes must be continued, including the possible use of plastics for this and for the nozzle.

There is little doubt that the rocket motor provides the best main propulsive unit for very short-range missiles or for those required to operate at very great heights. As missile range increases above about 20 miles the ram jet becomes more suitable, and at ranges greater than 100 miles the turbo-jet engine may have a place within limited height and speed boundaries.

Aerodynamic Form, Flight Performance and Control.—To establish the aerodynamic form a vast amount of basic aerodynamic data are required on air forces exerted on aerofoils and bodies of different shapes and sizes over the whole speed, height and manœuvrability range of the missile. One must deduce from these data, and check in wind tunnels or by full-flight experiment, the forces and moments generated on combinations of those components. A typical deduced curve is shown in Fig. 17 which shows the total drag force on a missile plotted against speed. The sharp rise in the curve in the region of the speed of sound is due to the rise in the value of the drag coefficient in this region. Thrust curves for ram-jet and rocket motors can then be superimposed, chosen to ensure the required acceleration in straight flight and the excess thrust available to counter the additional drag induced in manœuvres.

Finality can be reached only after the closest consideration of the control problems. An example is the choice between a four-wing or cruciform configuration and a two-wing system as used on aircraft. The cruciform system enables wing incidence to be applied simultaneously in two directions at right angles to one another and a turn can thereby be induced in any required direction with a lag depending only on the time required to apply wing incidence. The other scheme,

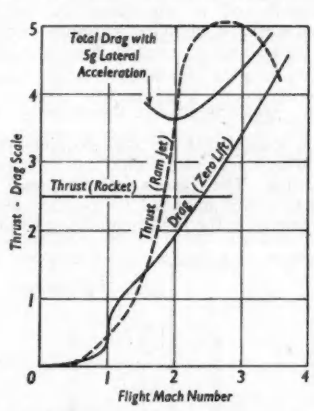


Fig. 17—Thrust and drag curves for ram-jet and rocket missiles

commonly known as "twist-and-steer," first requires the missile to be banked until its wings lie in a plane at right angles to the required direction of turn and then requires the application of incidence in that direction, the whole process thereby involving more time lag.

Clearly, these alternative systems present the automatic-control designer with very different problems, not the least of which is the avoidance of the situation where an underdamped twist-and-steer system, trying to steer steadily towards its target, would necessitate frequent excursions of just less than 180 deg. bank.

Possibly the most difficult aerodynamic

problem is to provide satisfactory aerodynamic controls and to minimise the forces required to operate them. The lift force which is generated on 1 square foot of lifting surface in a free airstream at $M=2$ and at 10 deg. incidence is 2400 lb at sea level and, unfortunately, the centre of pressure changes with speed. It is necessary, therefore, to select the hinge line carefully so as to minimise the servo-power required to move a control of this kind very quickly. Even with care the peak requirements of a twist-and-steer control system for a missile of this kind can amount to 10 h.p. or 20 h.p.

Another effect arises if the control surface is mounted, as in most aeroplane controls, as a flap behind a fixed surface. When the control is deflected, the moment due to the lift force reacts on the fixed surface and causes it to twist and apply a moment on the missile in opposition to the control moment. Control reversal can result from this effect. This can be minimised by ensuring that the fixed surface is adequately stiff in torsion, or avoided by using all-moving control surfaces separate from any other fixed surface. This effect is termed "aero-elasticity" and the effect increases in severity as flight speeds rise. Another most troublesome aero-elastic effect emerges in the form of body flexure. Modes of oscillation can be generated which are, unfortunately, detected by accelerometers and gyroscopes in the control system, and which can thereby induce unwanted missile movement.

It is becoming apparent that the guided missile is a complex servo-loop in which the reaction of the function of every component is felt through the loop and into which much spurious and disturbing information is injected, for example, by aero-elastic effects, radar "noise" and movement of the target. It remains for the automatic-control designer to close this complex loop and to ensure not only stable flight but the best possible result in terms of accuracy of the missile.

Attention has been concentrated on outlining a few of the problems arising in the development of the ground-to-air guided missile. Other types of weapon are based on quite different tactical and strategic requirements and many special technical problems arise. However, there is not time to make further mention of these other weapons, and instead two remaining aspects common to all types will be discussed.

(To be continued)

Testing the Performance of Precision Ball Bearings

By M. GRANEEK, A.M.I.E.E., and H. L. WUNSCH, A.M.I.Mech.E.

Little information is available on the performance of high-precision ball bearings of small diameter when operating at very high speeds. A machine has, therefore, been developed which provides a continuous measurement of frictional torque at speeds up to 50,000 r.p.m. of small ball bearings under defined axial and radial loading. This article is primarily concerned with the development of the testing machine. But the ultimate object in view is the correlation of the dimensional accuracy of the bearings with overall performance. The torque-speed characteristics of particular types of bearing will also be investigated.

THE equipment shown in Fig. 1 consists essentially of a high-speed driving unit, arrangements for applying variable axial and radial loads, and a sensitive recording torque meter.

High-Speed Air Bearings

It was decided that the driving spindle for the ball bearing under test should run in a pair of air bearings. The reasons for this choice were, first, that it was intended to include vibration measurements in the performance test so that all auxiliary equipment should be as free from vibration as possible, and, secondly, because of the ultimate high speeds envisaged (up to 100,000 r.p.m.). An air bearing, based on existing practice,* was therefore developed in the laboratory and tested to determine its load capacity.

As shown in Fig. 2, the journal bearings are each 1in long and 1in diameter with a radial clearance between spindle and bearing of 0·001in. Compressed air is supplied to the gap between the spindle and each bearing through three constrictions, 0·028in diameter and ¼in long, displaced 120 deg. from each other around the circumference. For test purposes, radial load was applied symmetrically to the spindle by loading a pulley block in the position indicated in Fig. 2. Axial load was applied by dead weights, the force acting through a bell crank lever to the ball-ended spindle. Reaction to the axial load was provided by air pressure at the conical end of the spindle, compressed air being admitted through a constriction to the space between the end of the spindle and the thrust bearing. When axial load at the right-hand end of the spindle (Fig. 2) is increased the spindle moves to the left and reduces the air gap at the conical surface. The increase in escapement resistance at the cone produces an increase in pressure at the end of the spindle which automatically balances the axial load. This pressure is measured by a pressure gauge and the relation between it and axial load was determined by direct experiment. This particular form of thrust bearing was used in preference to a constricted jet blowing on to the normal shaft end because the use of the conical design allows greater mechanical clearances and it also provides a better pressure distribution with improved load capacity for a given size of bearing.

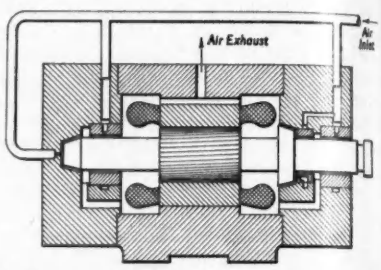


Fig. 3—The rotor of the driving motor is supported in air bearings and has air thrust bearings

Tests on the experimental bearing showed that it was capable of supporting a symmetrical radial load of 40 lb or an axial load of 30 lb when the air supply pressure was 60 lb per square inch. The spindle was run at speeds up to 40,000 r.p.m., and the load capacity of the bearings was not appreciably affected by speeds up to this value.

High-Speed Motor

The driving unit is a three-phase, two-pole, high-frequency motor supplied from a variable-speed, motor-alternator set. Initial tests were carried out with a water-cooled motor, designed by the Hoffmann Manufacturing Company, and incorporating a B.T.H. stator-rotor unit fitted with precision ball bearings. For the reasons stated above, it was considered desirable not to use ball bearings in the final design, and a new motor was developed in the laboratory using a similar stator-rotor unit with air bearings.

As shown in the cross-sectional drawing (Fig. 3), the journal and thrust bearings in the motor are similar to those previously described. Most of the exhaust air from the bearings is made to pass over the stator laminations before being released to atmosphere, and this provides adequate cooling. This motor has been run continuously for three hours at 60,000 r.p.m. on no load with a maximum temperature rise of 26 deg. Cent., as measured by a thermo-couple attached to the stator windings.

In order to obtain some design data for the thrust bearings, models of the two types of

* "Air Lubricated Bearings," P. M. Mueller, *Product Engineering*, August, 1951, pages 112–115.

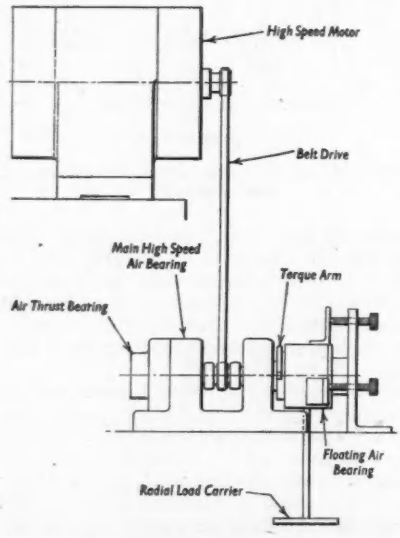


Fig. 1—Arrangement of equipment for testing ball bearings

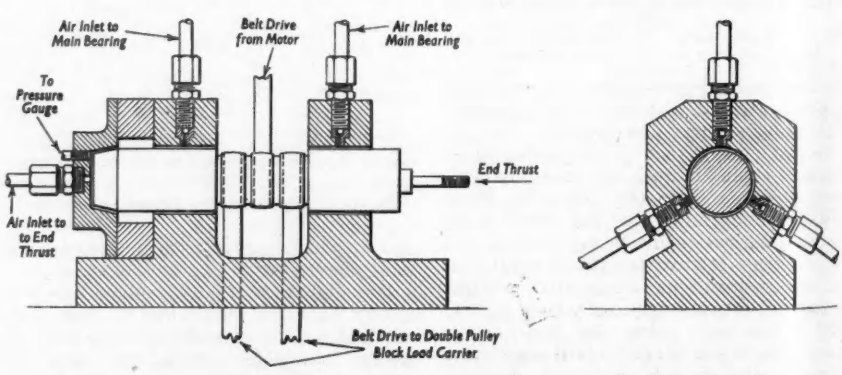

Air Inlet to Main Bearing
Belt Drive from Motor
Air Inlet to Main Bearing
To Pressure Gauge
End Thrust
Air Inlet to to End Thrust
Belt Drive to Double Pulley Block Load Carrier

Fig. 2—The driving spindle for the ball bearing under test runs in a pair of air bearings

conical bearing at the driving end and non-driving end respectively of the shaft (see Fig. 3) were made. In each case the displacement of the model shaft was measured for various values of axial load and a combined graph of the results is given in Fig. 4. The abscissa origin corresponds to the axial position of the shaft when the shaft and bearing cones at the non-driving end are in contact and a total axial clearance of 0·020in is assumed. The difference between the ordinates, corresponding to any displacement of the shaft, indicates the axial load which the bearings will withstand and the point of intersection of the two curves indicates the neutral position of the shaft, i.e. with no external axial load. Provision must be made for a maximum radial movement of the shaft of ±0·001in, the clearance at the journal bearings, so that axial movement of the shaft is not permissible in the regions between the origins of the two curves and displacements of 0·004in from these points. (The cone apex angle is 28 deg. for each bearing and tan 14 deg.=0·25). The working range is, therefore, that shown between the dotted lines and the same maximum axial loads which may be applied to the motor, as measured from the graph, are 21 lb inwards and 13 lb outwards. The motor is capable of withstanding a radial load at the driving pulley of 20 lb determined experimentally. Fig. 6 is an illustration of the new motor fitted with air bearings.

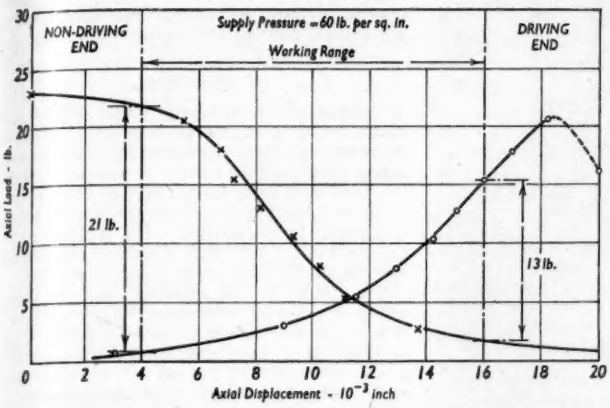


Fig. 4—Displacement of rotor of driving motor with variation of axial thrust

The motor is fitted with a crowned pulley of diameter $\frac{7}{8}$in and width $\frac{3}{8}$in, the amount of radial crowning being $^1/_{64}$in. An endless belt, $\frac{5}{16}$in wide and $^1/_{32}$in thick, made of pure tussah silk impregnated with linseed oil dressing, is used to transmit the drive to the spindle located vertically below the motor. This type of belt has been found to operate very satisfactorily at spindle speeds up to 50,000 r.p.m., i.e. the maximum speed achieved with the machine to date.

At these high speeds the shafts must be dynamically balanced to a high degree of accuracy. To this end an electronic dynamic balancing machine has been used capable of detecting an amount of unbalance equal to W/50,000 oz-in, where W is the weight of the shaft in ounces.

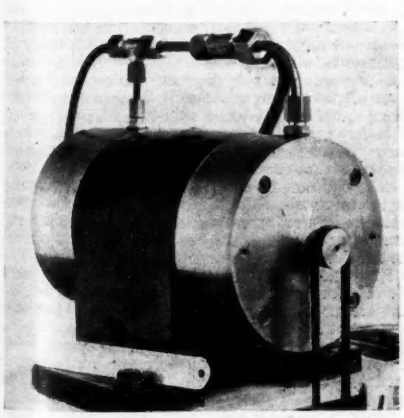


Fig. 6—Driving motor

"Floating" Air Bearing

The inner race of the test bearing is held in position on the end of the high-speed spindle by a nut. The outer race is clamped axially in a housing which forms the inner of a "floating" air bearing. The bush of this air bearing has two rows of three inlet holes spaced 120 deg. apart, two of these inlets appearing in Fig. 6. Three angle brackets are fixed to the air bearing outer and the polished face of each bracket bears against a ball-ended stop, the upper one being shown in Fig. 7. In this way the air bearing outer is free to move in a plane at right angles to the spindle axis, which permits radial self-alignment of the inner and outer races of the test bearing in the machine.

Radial load can be applied to the test bearing by the weight carrier shown in Fig. 7. Axial load is applied by admitting air under pressure to the space containing the blanked-off end of the test bearing outer housing, the axial load being measured by the calibrated pressure gauge at the conical end of the spindle as described earlier. Freedom of movement of the outer housing and adequate sealing of the compressed air providing the axial load is ensured by the use of the rubber disc shown in this diagram. By these means both radial and axial loads can be applied to the test bearing without imposing any frictional constraint on the outer race. Provision is also made for the supply of oil fog lubrication to the ball bearing.

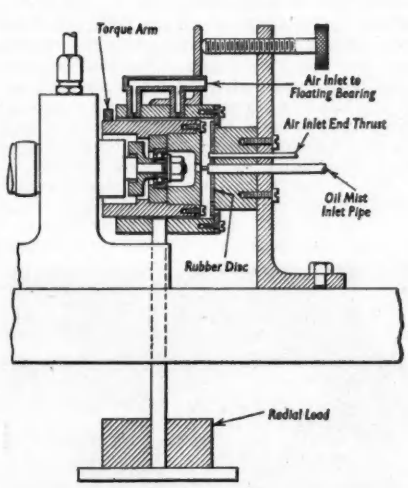


Fig. 7—The ball bearing under test is supported in a floating air bearing to which an end thrust and a radial load can be supplied

Torque Meter

Frictional torque in the rotating ball bearing is detected and measured with the aid of a torque arm (Fig. 5) fixed to the outer race housing. A photo-cell pick-up unit is arranged at one end of the arm to detect any movement of the arm produced by frictional torque in the test bearing. The photo-cell signal is amplified by a conventional electronic amplifier and fed back to a moving coil wound on a copper former fixed to the end of the torque arm opposite to the pick-up. The coil moves in the field of a permanent magnet. The plan view of the coil former is made rectangular so that some axial movement of the torque arm is permissible, whilst a small magnetic air gap is retained. With the closed loop system described above the electro-magnetic pull of the coil continuously balances the external torques applied to the inner of the "floating" air bearing and the current in the coil bears a linear relationship to that torque since the magnetic field strength is constant. The coil is connected in series with a 25mA recorder, full-scale deflection of which corresponds to a torque of 20g.cm. Errors due to friction in the "floating" air bearing were estimated to be less than 0·1g.cm. The torque meter was calibrated by a preliminary test in which weights were placed on a carrier supported on a knife-edge at a known distance from the centre of rotation of the torque arm. Damping is provided by an oil dashpot as shown in Fig. 5.

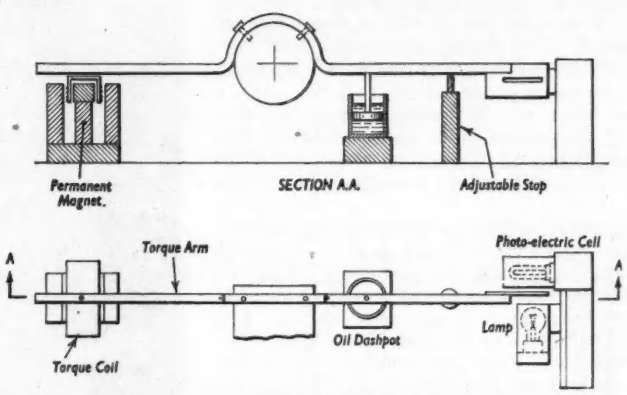


Fig. 5—Arrangement for measuring the frictional torque of the bearing

Zero adjustment is provided by means of an adjustable small rider weight. It was found necessary in practice to adjust the zero when the test bearing was changed or whenever radial load was altered. The main reason for this phenomenon is that the radial load, which acts in a vertical line through the geometrical centre of the "floating" air bearing bore, is not generally in line with the reaction to the radial load which acts vertically upwards through the geometrical centre of the test bearing inner race. Eccentricity of the inner race relative to the

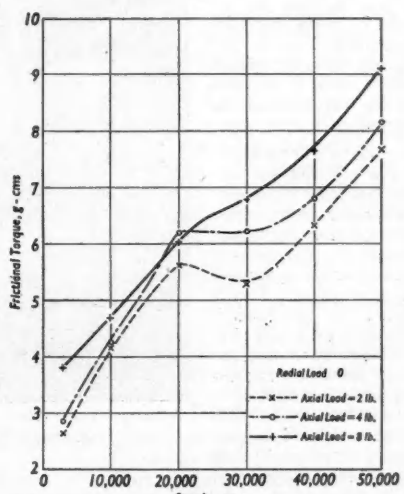


Fig. 8—Relationship between frictional torque and speed at various axial loads with zero radial load

centre of rotation of the driving spindle is unimportant in this respect as tests are normally carried out at high speeds of rotation and average values of frictional torque measured over several seconds are usually required. Eccentricity of the outer race relative to the air bearing does, however, produce an important effect. It is of interest to note that a radial load of 4 lb in conjunction with an overall average eccentricity of 0·0002in would produce a zero error of que retorading equivalent to about

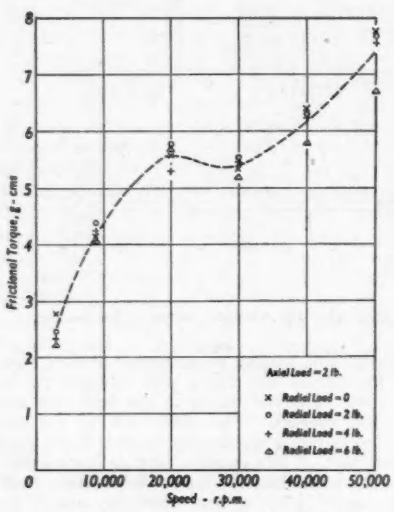


Fig. 9—Relationship between frictional torque and speed at various radial loads with zero axial load

1g.cm. For this reason it is necessary to check the zero reading between tests. This is done by holding the test bearing in a fixed position with the aid of a simple fixture which clips over the driving spindle, tapping the spindle lightly to reduce static friction in the test bearing and noting the reading on the torque recorder. The process is repeated at several different positions of azimuth of the test bearing and an average value of torque obtained on the recorder. This average value is made equal to zero by adjustment of the rider weight. The accuracy of zero setting by this method is considered to be within ±0·1g.cm. of the true setting.

Speed Measurement

Rotational speed of the test bearing is measured photo-electrically. One-half of the circumference of the driving spindle over a short axial length is painted black. Light from a small lamp source is reflected from this part of the shaft on to a photo-cell and the electrical impulses picked up (one per revolution of the shaft) are transmitted to a frequency monitor which can be suitably calibrated in revolutions per minute.

Safety Devices

The rotating parts of the machine are totally enclosed in an expanded metal frame to protect personnel. To prevent damage to the equipment in case of air supply failure a microswitch operated by a Bourdon tube is made to open the main contactor supplying the motor-alternator set and so stop the high-speed motor, if the air supply pressure falls below about 80 per cent of its rated value. A small relay is connected in series with the torque meter coil and recorder to provide protection for the equipment in the event of excess friction being developed in the test bearing. Operation of this relay due to excess frictional torque also stops the high-speed motor by the action of opening the main contactor.

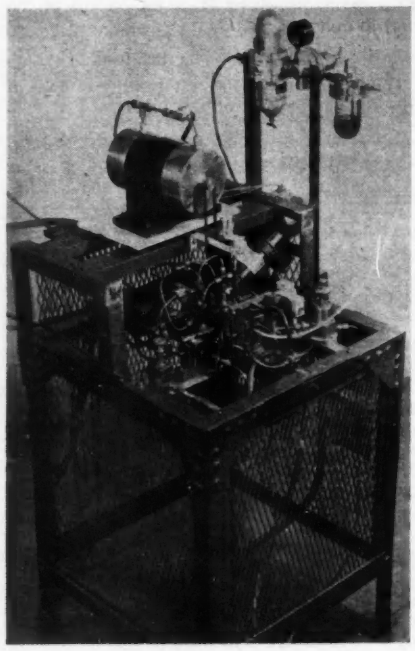


Fig. 11—Appearance of equipment

Results

A series of preliminary tests has been carried out, mainly for the purpose of testing the machine, but also to obtain some information on the torque-speed characteristics of a particular type of ball bearing. The bearing is a precision one of 5mm bore and of angular contact type.

The test procedure consists in giving the bearing five minutes of oil fog lubrication and then running it for one hour under the selected load and speed conditions. The value of frictional torque reached at the end of the hour run is then taken as the value for the particular conditions. Two tests were carried out for each set of conditions and the results obtained were found to agree closely in the majority of cases.

Figs. 8 and 9 show the torque-speed curves for constant radial and constant axial load respectively, the results in each case being the mean values for the five bearings tested. It is too early yet to draw any firm conclusions from these results, but it would appear that, for this type of bearing, the axial load has a greater effect on frictional torque than the radial load within the load limits applied.

It is hoped to extend this work in the future by employing grease lubrication, both 5mm and larger bearings being tested, but a very large number of results will have to be obtained before any definite conclusions can be drawn.

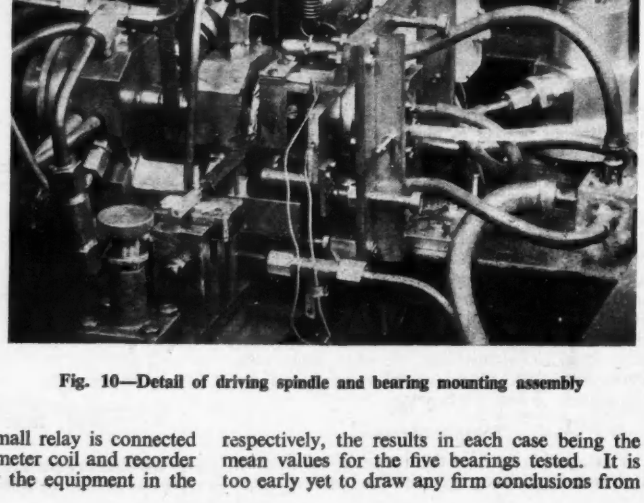


Fig. 10—Detail of driving spindle and bearing mounting assembly

Conclusions

The machine in its present form, illustrations of which are shown in Figs. 10 and 11, is capable of testing ball bearings of bore 5mm or 10mm at speeds up to 50,000 r.p.m. The maximum values of radial and axial load which can be applied to the test bearing have been found to be about 8 lb and 10 lb respectively. The total air consumption is 13 cubic feet of free air per minute and the supply pressure 60 lb per square inch.

The design of the apparatus is now being modified to increase the range of test conditions. It is intended to enlarge the projected area of the air bearings so that both radial and axial loads of 20 lb each can be applied to the ball bearing under test. A new motor, with a smaller stator-rotor unit, has been designed with which it is hoped to increase the speed range up to 100,000 r.p.m.

Preliminary trials are also being carried out with a barium titanate piezo-electric pick-up in an attempt to measure vibration in the ball bearing under test.

Acknowledgments

The authors wish to express their thanks to Mr. W. H. Swayne, of the Hoffmann Manufacturing Company, who lent a high-speed motor, fitted with ball bearings, which facilitated the initial development work. Valuable assistance was also received from their colleague, Mr. T. W. Aitchison, who designed the electronic amplifiers used with the torque meter and speed-measuring devices and advised on the use of pick-ups. The work described above has been carried out under Admiralty contract in the Mechanisms and Metrology Division of the Mechanical Engineering Research Laboratory, as part of the research programme of the Mechanical Engineering Research Board. It is published by permission of the Director of the Laboratory.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1

ROTARY FORM RELIEVED GEAR CUTTERS

No. 2518 : 1954. Price 7s. 6d. This standard is intended to replace the original brief section in B.S. 122 : 1938, "Milling Cutters and Reamers," which dealt with rotary form relieved gear cutters. As a result of experience gained since the publication of the latter standard, it became clear that the information it provided was inadequate and was insufficient to ensure uniformity in the manufacture of such gear cutters.

The present standard recommends the use of the 20 deg. pressure angle for gear milling cutters, and a modified basic rack gear tooth profile designed to avoid undercutting in gears with a small number of teeth whilst allowing sufficient tips relief for teeth cut. An odontograph diagram accompanied by a table of dimensions for 1 D.P. cutters enables the cutter tooth profiles to be set out for the full range of cutters for gears from a twelve tooth pinion to a rack. Tables giving details of cutter sizes for a range of diametral pitches of 1 to 30 are included.

In recognition of the fact that 14½ deg. pressure angle cutters are still in fairly general demand for replacement and other purposes, an appendix gives a set of odontograph diagrams and tables to enable the full range of such cutters to be set out.

The standard draws attention to the fact that gears cut with form relieved cutters are satisfactory only if they are meshed together under conditions of service which are not severe. It is pointed out that such gears should not be made to mesh with generated gears unless a suitable reduction in the chordal tooth thickness of the gears is made. A special appendix is included giving a correction table for this purpose.

Other appendices deal with arbor and keyway sizes, the marking of cutters, ordering instructions and metric sizes.

Iron and Steel Institute

AUTUMN GENERAL MEETING

No. I

THE autumn general meeting of the Iron and Steel Institute was held on Wednesday and Thursday, November 17th and 18th, in London, with the president, the Hon. R. G. Lyttelton in the chair.

In his opening remarks the president said that a full programme of meetings had been arranged for next year. In addition to the annual meeting in April and the autumn meeting in November in London, an invitation had been received from the Lincolnshire Iron and Steel Institute to hold a special meeting in Scunthorpe from October 12th to 14th. In June there would be held the Joint Metallurgical Societies meeting in Europe. The programme in this country was from June 1st to 7th and was being arranged jointly by the Iron and Steel Institute and the Institute of Metals. He was very pleased to be able to announce that H.R.H. The Duke of Edinburgh had agreed to be Patron. Thereafter meetings were to be held at Dusseldorf, at Liege and in France.

It was announced that the council had nominated Sir Charles Bruce-Gardner, Bt., M.I.Mech.E., for election as president to take office at the annual general meeting in 1955 and to serve for one year.

The Secretary stated that, since the last general meeting, the following awards of Andrew Carnegie scholarships had been made: Mr. C. J. Ball (Queen's College, Cambridge), £410 to assist research on plastic deformation of metals; Mr. P. R. Vaughan Evans (University College, Swansea), £350 to assist research on the mechanical properties and internal stress of various strip steels after various isothermal treatments, and Mr. J. Wilcock (Liverpool University), £50 (second grant) to assist research on the influence of manganese, sulphur and the sulphur to manganese ratio on the kinetics of first stage graphitisation.

Finally, the president announced that the council had accepted with great pleasure a cordial invitation from the Chambre Syndicale de la Sidérurgie Française, in conjunction with the Société Française de la Métallurgie, to hold a meeting in Paris in 1956, probably in June.

The meeting then proceeded to the discussion of technical papers. The first paper was :—

THE FUTURE OF STEEL MELTING

By Professor M. W. Thring, M.A.

Synopsis

The fuel consumed in making steel will absorb an increasing fraction of the cost of the process as fuel supplies become scarcer. Hence the thermal efficiency of the process will have to improve. The best value at present is just over 20 per cent. To show the relative importance of various factors in improving this thermal efficiency the theoretical method of evaluating the heat transfer in an O.H. furnace developed in a previous paper is applied. It is concluded that the Siemens process could ultimately give a thermal efficiency of about 50 per cent on cold metal, and that the greatest improvement will come by increasing the air preheat, i.e. eliminating unpreheated excess air, and improving regenerator efficiency. However, the analysis shows that the Siemens process is not the ideal one for steelmaking when more than half the raw materials are cold scrap, because it does not make the best use of the lower-grade gas heat for counterflow preheating the charge, and because a large portion of the heat has to be supplied through a thick slag blanket. A continuous-counterflow steelmaking process is proposed, which would overcome these disadvantages and have a theoretical thermal efficiency of 70 per cent on cold metal.

Discussion

Mr. J. Mitchell (Stewarts and Lloyds, Ltd.): Like many others here, I am a great admirer of the work which Professor Thring has done and of some of the ideas which he has advanced, but in this paper when he starts to peep into the future I am afraid that he is looking down too narrow a lane. I think that the author is overlooking—though he has stated them clearly—the disadvantages, both thermal and metallurgical, of the open-hearth furnace and the fact (as it is to my mind) that there are alternative means of steelmaking, and that probably the future lies in that direction. I must say that the author's sketch of the materials being pushed down the ramp by a ram made me shudder. I am not an engineer, but I can picture what is going to happen there. The mass at the bottom is going to be tacky and the mass above it compressible, and the new scrap will be pushed in amongst the old. From a purely practical point of view we must regard that as impracticable.

The author has made a great point, and rightly, of the advantages which he is going to derive from a thin slag and a thin bath, but I submit that these advantages are purely illusory unless there is an intimate contact between the slag and the metal, and that is precisely what will not happen. On this question of melting down, in order to be fair to the process I ought to say that if the theoretical conditions justified it—I do not think that they would—and one ever had to deal with cold pig iron, it would melt that fairly well, but not scrap. We depend on the reactions from the pig iron for the effectiveness of the steelmaking process. I accept the disadvantages of the open-hearth process which the author lists, but I suggest that there is only one way to overcome them and that is to accept the somewhat revolutionary idea of generating the heat in the metal instead of trying to push it through the slag. The process in which that is done is the converter process. With the new oxygen techniques there is a superheat in the metal which makes it possible to use 30–40 per cent of scrap.

Dr. A. H. Leckie (Iron and Steel Board): If the author's suggestion that the Siemens furnace is no longer the right melting furnace is correct, the development plans of the steel industry will need some substantial modifications. Why is it that the Siemens furnace, which is now a hundred years old, is still the most important steelmaking unit in many of the major countries, and even in America, where, we are told, there is always a great readiness to try anything new? I do not think that the steel industry is particularly backward in its ideas, and I submit that the Siemens furnace is still with us because it is the best for its particular job. The main difficulty is that it is necessary to send a great deal of high-temperature heat out of the working chamber, and regenerators can recover only part of this. They are not, however, the end of the story; most modern open-hearth furnaces have waste heat boilers. If the author were to give us the theoretical efficiency of the best possible Siemens furnace equipped with the best possible waste heat boiler, I think that this would come more in the region of 65–70 per cent than of the 50 per cent maximum given in the paper. I do not suggest that the heat recovery potential of the waste heat boiler should be used to excuse inefficiency.

I have suggested that the author has not been quite fair to the Siemens furnace, and I am now going to argue that he has been too favourably predisposed to the counterflow system. I do not see that any account has been taken of the heat required to melt the slag-forming material. He has allowed for leakages, but so far as I can see all that he has done is to take 1·2 for a theoretical error; but his furnace, which has a stack 8·6ft high full of scrap, is going to need a lot of suction at the top or pressure at the bottom to make it work, so that there are bound to be some leaks or blowouts, and that may make an appreciable difference to the calculations. I think that water cooling will be needed, so that the efficiency may not be quite so good as he says.

The oxygen potential required to burn fuel efficiently will burn iron very efficiently, and the only reason why scrap melted in the Siemens furnace is not over-oxidised is that it is covered with slag; it is saved by the very feature of the Siemens furnace which the author condemns on grounds of heat transfer. Why do not we see gas-fired cupolas instead of inefficient ones using coke? With a gas-fired cupola the steel would be hopelessly over-oxidised, and that might happen with the author's shaft. Is the author satisfied that there will not be sulphur pick-up? He says that one of the advantages of his proposal is that " because the gases are fully burnt long before they come in contact with any metal . . . sulphur pick-up can be almost completely eliminated," but sulphur pick-up is quite serious even from completely burnt fuel if there is exposed iron and iron oxide, so that I do not think that his furnace would help there. It may be better than the Siemens furnace, but it will not overcome the problem of sulphur pick-up. Engineers will be able to think of other difficulties, but I do not want to give the impression that I think that the proposed counterflow furnace has no advantages. It has, I believe, a tremendous number, but I suggest that the author has overlooked a few of the snags, or at any rate has not dealt with them in the paper. I do not propose to refer to the other alternatives which the author mentions. The chief disadvantage of the recuperator and waste heat boiler is not so much the theoretical thermal disadvantages as that all these things will become hopelessly messed up with slag, and the heat transfer efficiency will go down quickly.

At the end of the paper the author mentions atomic energy. I am sorry that he did not say more about this in connection with the future of steel melting.

Dr. J. H. Chesters (The United Steel Companies, Ltd.): I agree with Dr. Leckie that the author's estimate of the efficiency of the open-hearth furnace is pessimistic, and that it would be fairer to include waste heat credits. I also feel that we are not at the end of the road by any means so far as the conventional open-hearth process is concerned. I believe that there is still a great future in intense combustion. We have talked here from time to time about the possibility of burning more fuel and getting more output and saving fuel thereby, and everything that has been done in the last four or five years has tended in that direction and shows that the more we can burn the less fuel we shall use per ton. I think that a figure for fuel consumption, allowing a reasonable credit for steam, even for a cold-charged furnace, of something less than 20 gallons per ton is not an impossible target.

Dr. T. P. Colclough (Iron and Steel Board): We are all fully conscious that the open-hearth furnace is not an efficient instrument. The preferable way of approaching this problem would be to make a critical

examination of why it is not so efficient and to see what steps can be taken to overcome the difficulties. The paper before us does not go quite in that direction.

Let us have a look at one or two of the details. First of all, the author has made far too simple an analysis of this problem. A steelmaking furnace has other jobs to do besides melting scrap and making steel. The furnace which is proposed has a hearth area of 1000 square feet for 60 tons, which works out at 16 square feet per ton of metal. I do not know of anybody who can make steel without having a slag on it. How much slag must there be ? It must have heat to form it and keep it molten, but there are no allowances whatever for that heat. We used to lay down the practical rule that to make good steel in a basic furnace one must have about 3in of slag to prevent the metal being burnt. The author, in his opening remarks, directed appropriate attention to the fact that the thickness of the slag layer is an important factor in the transfer of heat. If we work out what a 3in slag layer means in this furnace, we find that we have 35 per cent of slag on the metal. Secondly, I do not know whether the author has given any consideration whatever to the building of the chimney. We have had some experience of melting scrap in cupolas, and the longest time for which we could get one to stand up to the job was about eight hours in a reducing atmosphere. What would happen in this case, with the scrap being melted in an oxidising atmosphere, and the formation of ferrous silicates which would be running down the walls, I leave to your imagination.

The open-hearth furnace must be improved in efficiency. The way to improve it in efficiency is to make it as near tight as possible. The reason you do not get an efficient open-hearth furnace is that your regenerator system is not built in the correct way. If you wish to extract more heat from your waste gases (which is the way in which you improve your efficiency) the way to do it is to put your metal recuperators at the end of your present regenerators. That has been done. It is not a new idea. It was, I think, first introduced at Corby, where metal recuperators were put on the end of the regenerator chambers of soaking pits, in order to make them operate on blast-furnace gas.

[At this point, Professor Thring made an "interim" reply to some of the points raised.]

Dr. J. Pearson (B.I.S.R.A.) : The author says that in his furnace "the steel flows through the refining chamber in two hours, since the thinner slag and shallower bath possible with a continuous system will considerably accelerate the refining reactions." I do not think that there is any evidence at all for that. Even with conventional bath depths, most refining reactions appear to proceed quite fast, with the possible exception of carbon removal. Has the author any evidence that the carbon removal from a slow-moving shallow bath will be appreciably faster ? The author says also that his ideas about sulphur may not be as valid as he supposes. I suggest that the position is far less favourable. He says that the gases will be fully burnt long before they come in contact with any metal, "so that even with high-sulphur fuels sulphur pick-up can be almost completely eliminated." This implies a knowledge of the mechanism of sulphur pick-up which I should be pleased to possess. We do not know completely how sulphur is picked up, but present knowledge would lead us to think that the proposed furnace is about the worst which we could imagine for sulphur. It has a scrap heating column, and steel without slag cover is subjected to the action of gases containing a good deal of sulphur. It is hard to think that there is no sulphur pick-up, and unless the partial pressure of SO_2 were very large indeed there should be a very large pick-up. In the all-scrap process the waste gases, containing SO_2, oxygen and water vapour, are cooled from 1600 deg. to 170 deg. Cent. in a column which contains rusty scrap or surfaces which are oxidised, and in this range we get SO_2+O combining to give SO_3, which will condense to give sulphuric acid. That will react with the material and give us iron sulphate, which will decompose when it gets lower in the column, and we shall get sulphur pick-up from that. It seems to me that the author has arranged that any sulphur which ever gets into the furnace never gets out of it. We now know that the conditions which are favourable to sulphur pick-up from the gas via the slag to the metal are those present when the gases are not completely combusted. In the author's furnace the position where there is any non-combusted gas is just where the steel leaves, so that there is no time for any sulphur pick-up to be removed. The author has done away with the large doors and put tiny peepholes at the side. How will he fettle his furnace ? It seems to me that it will be very difficult.

Dr. C. A. Edwards, F.R.S. (Swansea) : I agree with what has already been said about sulphur pick-up. I think that the author's proposal is going to lead to very much more sulphur pick-up than we now get in the ordinary open-hearth furnace, because the whole of the scrap is being exposed during the whole of the melting period to these waste gases, whereas in the ordinary basic open-hearth as at present used a good deal of the scrap is well below the slag level as soon as hot metal is put into the furnace. I believe, however, that it might be possible to minimise the sulphur pick-up, which is so serious in open-hearth practice, by having a single directional flow in the open-hearth, because in those conditions we might quickly be able to ascertain just where the maximum degree of sulphur pick-up occurs. If it is at the outgoing end of the ordinary furnace perhaps the bulk of the scrap could be placed in that position, thereby decreasing the rather heavy load of sulphur pick-up which we now obtain.

Author's Reply

Professor M. W. Thring said in the course of his reply : We began with a suggestion that the open-hearth was not the process of the future at all, but that the Bessemer was the process of the future. I do not think that I need comment on that. I was hoping that some of the later contributors would answer it. They have done so to some extent by saying that the open-hearth is much better than I thought it was. I agree with those comments. If the paper makes the open-hearth "pull its socks up," so much the better. The suggestions made for the improvement of the open-hearth are very interesting from that point of view. We have had suggestions for putting the recuperators at the end of the regenerators, for the elimination of leaks in the open-hearth, and for the elimination of water cooling, and Dr. Chesters' point about intense combustion. It is clear, therefore, that the open-hearth can go a long way further than it has gone already, and I am extremely interested in its going further and think it will be improved enormously.

I still think, however, that there is room for trying to answer criticisms of the new process. To summarise them, first of all there are the criticisms about what happens in the bath of the proposed process, and Dr. Pearson's criticism that under the flame we shall get sulphur pick-up by the outgoing steel, because the gases are not fully burnt. To some extent Dr. Pearson's two criticisms about sulphur are self-contradictory, because, on the one hand, he blames me for having unburnt gases and says that there will be a lot of pick-up there ; and, on the other hand, he says that even when they are fully burnt in the column we shall still get a lot of pick-up.

I think that some of the arguments raised against the paper answer themselves. Apparently the open-hearth furnace manages to get good heat transfer to the scrap and not to oxidise the scrap and not to get sulphur pick-up because the scrap is always underneath the slag cover, but it gets a good heat transfer through the slag cover. I criticise it on that point and say it is because it is under the slag cover that it is difficult to get heat in. That brings me to the question of the processes in the column. Here we have metallurgical criticisms, and particularly that the scrap will oxidise away entirely and will reach the bottom of the column entirely as iron oxide. Here the perfect answer is that given by Dr. Chesters—try it and see. Other criticisms of the working of the column include the contention that we do not know exactly what the convection heat transfer coefficient is. The only way to answer that would be to find out ; but the indications are that the size of the column would not be unreasonable from that point of view, and, if these difficulties about oxidation and sulphur pick-up are not excessive, I still think that the incoming scrap and pig iron are the best things to use the low-grade heat from the process for, and that is why I think it is a proper step forward to take. It has been said that the refractories will not stand up, and there again we shall have to try and see. I do not think that the refractory makers would admit that that was an impossible problem.

Finally, we have had criticisms of the air heater, and it is said that I have been too optimistic in calculating the efficiency. Furtunately, however, dropping the efficiency of the air heater from 80 to 70 per cent or even to 60 per cent does not upset the overall heat balance too badly—only a few per cent—and there is still a very considerable advantage. It has been said that it would be impossible to fettle the bath. There is always a tendency to think in terms of the process which has been operated for the last hundred years. With a semi-continuous or continuous process I think that the fettling problem would be quite different from the present one. At present the bottom of the bath has to stand all the different stages in the melting process and therefore has to be a compromise between the ideal materials for all these stages. With a semi-continuous or continuous process the material would be right for each stage at the right place, and we could get material which would last longer than it does at present, so that it would only be necessary to patch up the bottom once a week when the furnace was emptied. The problem of the mechanism of introducing the fettling material could be solved without the doors at present supplied to the open-hearth furnace. It is said that I have not allowed in the process for the heat to melt the slag materials. It will lower the efficiency, but not so much as to bring it back to the level of the present open-hearth furnace.

(*To be continued*)

Radio Compass for Civil Aircraft

OUR illustrations show the components of a radio compass which was developed by The General Electric Company, Ltd., in close collaboration with the Royal Aircraft Establishment, to a Ministry of Supply specification and is now available for use by civil aircraft. Its function is to determine position and course and to home an aircraft on a transmitting station. Essentially, therefore, the equipment consists of a receiver and loop assembly designed to work in conjunction with any known ground transmitting station operating in the frequency band 150 to 1500 kc/s. It also provides facilities for normal radio reception in the medium waveband.

In its commercial form the G.E.C. radio compass incorporates an improved design of loop and loop-operating mechanism. The equipment is operated by all-electric remote controls ; cathode followers are used for loop matching ; and a separate heterodyne oscillator is provided for C.W. reception.

As shown in the first illustration, the complete equipment consists of two indicators, *A* and *B*, a receiver *C*, a loop assembly *D*, two control boxes *E*, a junction box *F*, a cathode follower unit *G*, and a desiccator *H*. One of the indicators, *A*, incorporates a compass and is driven by a repeater from the gyro compass, enabling bearings to be related direct to north, in addition to the aircraft heading.

In operation, the equipment provides four facilities, all controlled from a service switch on the control boxes, which has an "Off" position as well as the four operating positions. When the switch is set to "Tune" the equipment operates as a normal sensitive communication receiver, giving all-round reception on a sense aerial for tuning, traffic reception or station identification. Remote volume control operates on the audio-frequency amplifier only, and full automatic volume control is operative.

When the switch is tuned to "Nav." the arrangement is as described above, except that the automatic volume control is replaced by full-range manual control on both r.f. and i.f. amplifiers. This arrangement, with the note filter switched in, is provided specially for use with medium frequency ranges or track guides which are tone modulated at approximately 1000 c/s with polar diagram keying to give an equi-signal track with interlocking A-N off-course signals.

Turning the service switch to "A.D.F." brings into use the electronic loop switching circuits and servo mechanisms for automatic loop positioning, discrimination being provided to avoid ambiguity in the sense of the bearings indicated. Automatic volume control operates on this facility and a separate a.v.c. line is provided for the loop amplifier while manual volume control operates on the a.f. amplifier only. The compass provides reliable bearings on field strengths of 50 microvolts per metre, though, in taking bearings on weak signals, the receiver should always be carefully monitored by the telephones. A "No Signal" indicator is provided, operating on this service, which confirms whether the signal on which the user is homing is still being transmitted.

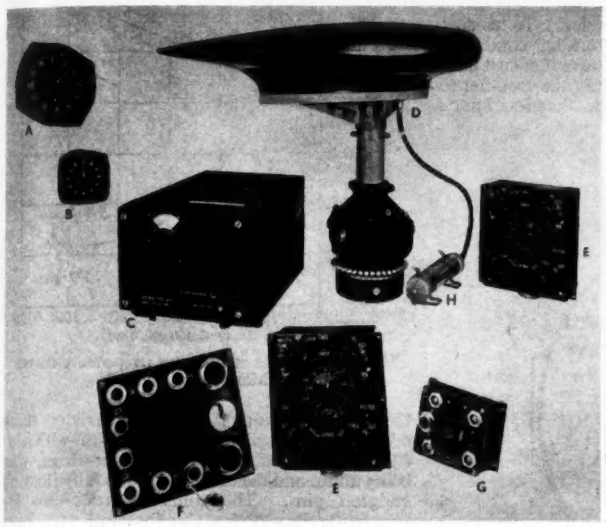
When the service switch is turned to "Loop" the sense aerial is eliminated and reception is on loop with full-range r.f. manual volume control. Loop rotation is by variable speed reversible manual control and both note filter and heterodyne oscillator will be in use on weak signals. The loop indicator reading to be noted on very weak signals is the mean of two points at which the wanted signal is just audible above the background noise. To check the sense of the bearing the loop is rotated clockwise (increased reading in degrees) by not more than 15 deg. If, on depressing the sense button, a decrease of signal output is observed, the bearing is correct. Otherwise the loop must be further rotated to a total of approximately 180 deg. and the reciprocal bearing accurately determined. Independent operation of both note filter and heterodyne oscillator is available on all four facilities.

The receiver employs a sensitive superheterodyne circuit, following a loop amplifier and balanced modulator. A servo amplifier receives the modulation obtained by mixing sense and loop signals, amplifies it and supplies power to drive the loop motor, thus rotating the loop in a direction always approaching its minimum. The power supplies are derived from a rotary generator mounted at the back of the receiver, which converts a standard 24–28V aircraft supply into 250V, d.c., and 35V, a.c. The receiver is unit constructed for ease of servicing and can be taken apart into ten sub-assemblies. It contains twenty-one valves, the heaters being supplied direct from the d.c. supply voltage.

By using specially developed high-permeability iron dust cores for the loop it has been possible to produce the assembly in a flattened rectangular form (as illustrated), and to enclose it in a flattened housing for external mounting, reducing the drag associated with this assembly by two-thirds. As an alternative installation, the loop is recessed and covered with plastics sheet conforming to the contour of the fuselage, thus eliminating the drag. The spindle carrying the loop is driven through a differential gear by two motors, so that, when the motor speeds are equal, the spindle is stationary.

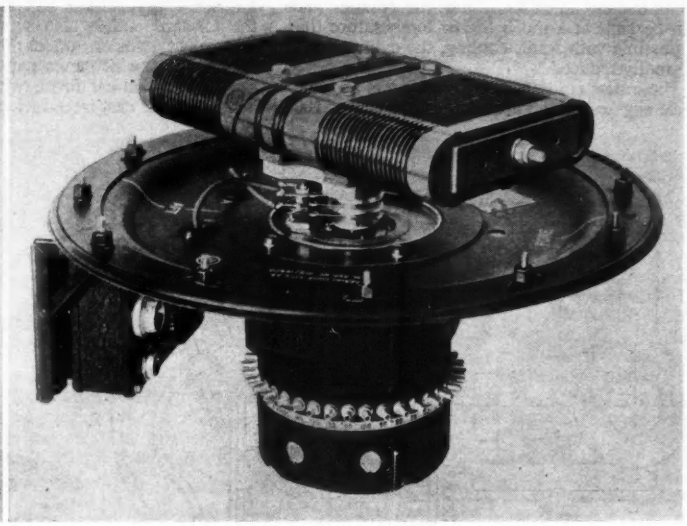
A scale giving an uncorrected bearing is attached to the loop spindle. A second scale is driven from the loop via a device for quadrantal error correction. Adjustment can be made every 10 deg. and a maximum quadrantal correction of 20 deg. can be made. After correction the loop bearing is translated into electrical co-ordinates by an improved Desynn potentiometer, which feeds the two indicators for the pilot and the navigator.

The instrument described here is made by Salford Electrical Instruments, Ltd., an associated company of The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2.



A, *B*} Indicators. *C*—Receiver. *D*—Loop assembly. *E*—Two control boxes. *F*—Junction box. *G*—Cathode follower. *H*—Desiccator.

Components of the radio compass which operates in conjunction with any known ground transmitting station in the 150-1500 kc/s frequency band



The form of loop assembly shown here is housed in a recess in the fuselage. It is covered with a plastic sheet moulded to the fuselage surface to avoid any projection

Indian Steel Plants

THREE countries have offered to establish steel plants in India, namely, Britain, Soviet Russia and Japan, and the Government of India is studying the various proposals through its expert committee in collaboration with the technical advisers of the Planning Commission. Soviet technicians are now in India engaged in preliminary discussions with the Government's experts and their proposals, which are in the tentative stage at the moment, will be finalised on their return home after the discussions.

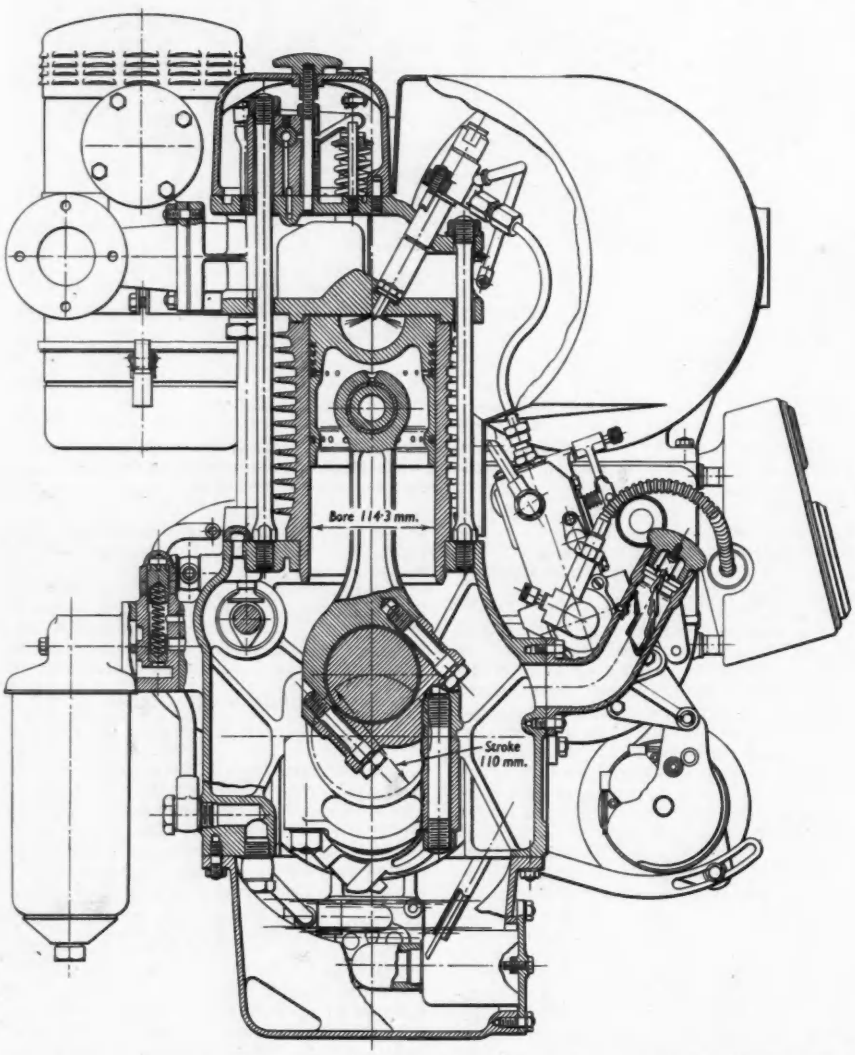
The attractions of the British offer are that the proposed plant will go into production in three years' time and that the entire machinery, constituting 60 per cent of the capital investment, will be supplied by the British steel manufacturing interests. The total investment, which will depend upon the size of the plant and its capacity, will be repaid in instalments spread over ten years and will probably bear an interest of about 4 per cent. Indian industrialists will also participate in the project, which will be Government financed to the extent of Rs. 15 crores at the start, but will be managed by private enterprise. It is understood that there are two schemes in the British offer : one envisages production of 675,000 tons of steel at an estimated cost of Rs. 62 crores (£46,500,000) ; and the second, which is considered preferable, is designed for a capacity of 1,000,000 tons at an estimated cost of about Rs. 90 to Rs. 95 crores (£67,500,000 to £71,250,000).

Air-Cooled Diesel Engines

THE increasing attention given to the possibilities of air-cooled engines has prompted J. and H. McLaren, Ltd., Leeds, to develop a new range of such engines, with powers ranging from 13 b.h.p. to 96 b.h.p., and these are now introduced as the Petter-McLaren P.D. range. By adopting air cooling for these new units the designers have eliminated the problems usually associated with the use of water cooling systems and have effected certain economies. Other advantages associated with the adoption of air cooling is that the engine reaches optimum running temperature very quickly, at which level it can be maintained and, since the cylinder walls can be kept at a much higher temperature than is possible with water cooling, the cylinder wear is greatly reduced.

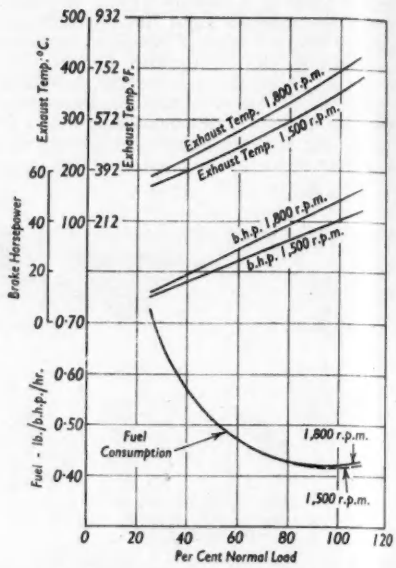
These new cold starting power units are four-cycle engines, which are designed to run at 1800 r.p.m., have a bore and stroke of 114·3mm and 110mm respectively, and develop 12 b.h.p. per cylinder at the conservative rating of 77 lb per square inch b.m.e.p. Two, three, four, six and eight-cylinder models are available, and in order to limit the length of the engines and to avoid objectionable torsional vibrations, the two, three and four-cylinder units are built as in-line engines, while the six and eight-cylinder models are constructed with two banks of cylinders set at an included angle of 90 deg. We include a line drawing showing a vertical section of an in-line engine and a photograph of an eight-cylinder vee engine.

The cast iron crankcase carries the "Meehanite" cast iron crankshaft, which is underslung and supported in copper-lead bearings placed between each cylinder. There are three, four, or five bearings according to the number of cylinders for the in-line engines and four bearings for the vee six-cylinder unit, while the vee eight-cylinder model has five crankshaft bearings. To provide adaptability for mounting there are side facings on the crankcase to take brackets to enable the engine to be used for transport or industrial applications. A trunnion support at the forward end is also supplied. To achieve uniform expansion under working conditions the cylinders, which are separate and of cast iron, are of symmetrical form, while the well-finned heads, also of cast iron, include directional ports and, together with the cylinders, are connected to the crankcase by six long through bolts of 65-ton steel.



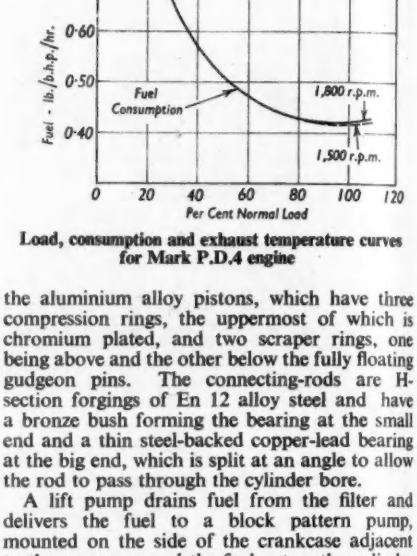
Cross section through an in-line engine. The drawing applies to two, three, and four-cylinder engines

A cowling encloses the cylinder bank and a belt-driven axial-flow fan delivers sufficient cooling air, which, through the medium of the fins on the cylinders, maintains the engine at an efficient running temperature at all loads and speeds. Guide vanes at each cylinder ensure that the air provides maximum cooling effect by directing it over the maximum surface area. A lubricating oil cooler is also fitted inside the cowling. Each cylinder has one exhaust valve and one masked inlet valve, which are operated by rocker arms and push rods actuated by cams on a camshaft of case-hardened En 32 forged steel, carried in solid lead-bronze bearings and driven by a gear train from the crankshaft. There is a hemispherical bowl in the crown of the aluminium alloy pistons, which have three compression rings, the uppermost of which is chromium plated, and two scraper rings, one being above and the other below the fully floating gudgeon pins. The connecting-rods are H-section forgings of En 12 alloy steel and have a bronze bush forming the bearing at the small end and a thin steel-backed copper-lead bearing at the big end, which is split at an angle to allow the rod to pass through the cylinder bore.

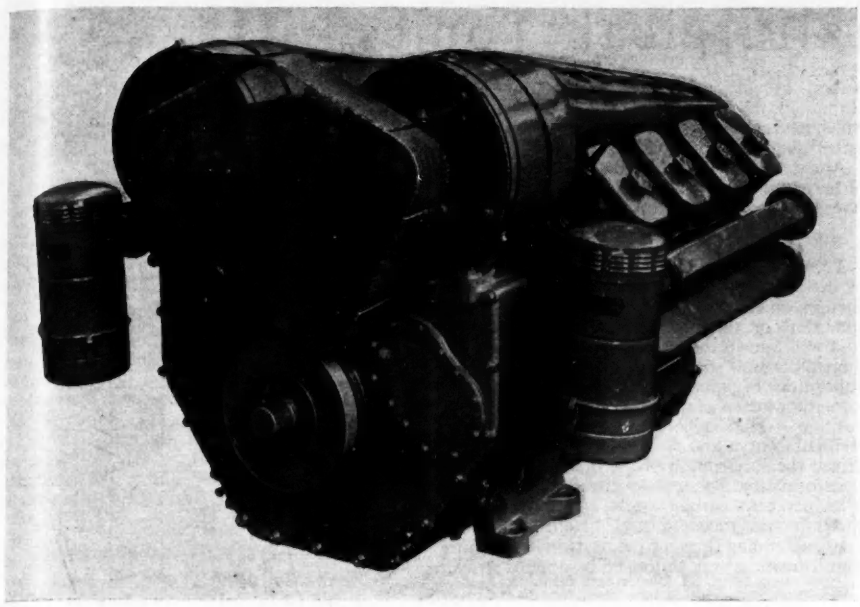


Load, consumption and exhaust temperature curves for Mark P.D.4 engine

A lift pump drains fuel from the filter and delivers the fuel to a block pattern pump, mounted on the side of the crankcase adjacent to the governor, and the fuel enters the cylinder through injectors having multi-hole nozzles, which are so mounted on the cylinder head that the spray is centrally disposed in the combustion chamber. For the vee engines the fuel injection pump is mounted between the cylinder banks and the eight-cylinder unit has two block pumps arranged in tandem. The cylinder walls and



Torque and fuel curves for Mark P.D.4 engine



Mk. PDV8, eight-cylinder vee diesel engine

small end bearings are splash lubricated, while all the crankshaft, camshaft and timing gear bearings and the rocker gear are pressure lubricated. A gear pattern pump draws the lubricating oil from a wet sump and delivers the oil at a pressure of about 40 lb per square inch to the lubricating system, which incorporates a "Purolator" filter, and includes a finned tube oil cooler, which, as already mentioned, is mounted in the air ducting.

A centrifugal governor, built into the fuel pump driving gear wheel and totally enclosed, controls the engine speed, which can be adjusted by 10 per cent, up or down. By changing the speeder spring any constant speed between 1000 r.p.m. and 1800 r.p.m. can be obtained. A variable-speed governor is also available. The exhaust manifolds are arranged to discharge at either end and Burgess oil-washed air cleaners are provided. For the in-line engines 12V electric starting is standard, while for the vee engines a 24V electric starter with dynamo is fitted. The standard rotation of the engines is anti-clockwise when viewed from the flywheel end. Power is taken from the flywheel end either by direct coupling or extension shaft and, if required, power up to 25 per cent may be taken from the crankshaft at the gear end.

Our graphs show the typical performance curves relating to the Mark P.D.4 engine, taken at normal temperature and pressure, but we understand that tests already carried out have proved that the new range of engines are suitable for running under tropical conditions.

The following table gives power related to revolutions per minute and based upon a twelve-hour rating, the compression ratio being 16 : 1.

Power Speed Table

R.p.m.	1000	1200	1500	1800
	1 b.h.p.			
P.D. 2	13	16	20	24
P.D. 3	19	24	30	36
P.D. 4	26	32	40	48
P.D.V. 6	40	48	60	72
P.D.V. 8	53	63	80	96

For the in-line engines the weights including electric starting and light flywheel are 900 lb, 1050 lb and 1200 lb for the Mark P.D.2, P.D.3 and P.D.4 models respectively, while the bare engine weights of the P.D.V.6 and P.D.V.8 engines are respectively 1600 lb and 1900 lb.

INTERNATIONAL MACHINE TOOL EXHIBITION, 1956.—The dates previously announced for the International Machine Tool Exhibition to be held at Olympia, London, in 1956, have been altered. The exhibition, organised by the Machine Tool Trades Association, will now take place from June 22 to July 6, 1956.

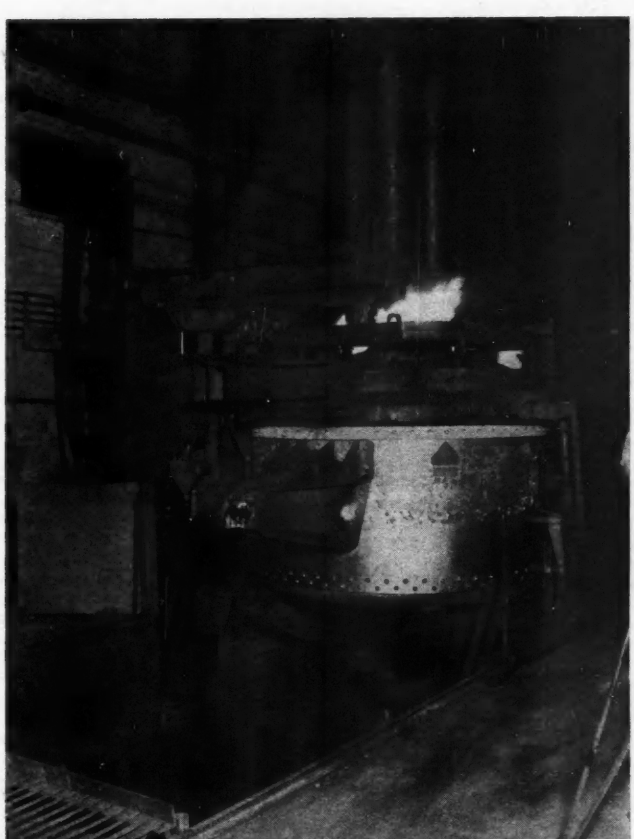
Arc Furnace with Hydraulic Electrode Feed

A NEW arc furnace for steel melting has been supplied to the Clyde Alloy Steel Company, Ltd., by G.W.B. Furnaces, Ltd., of Dudley, Worcs. The furnace was made to the designs of L. Tagliaferri, of Milan, and it incorporates this company's hydraulic system of electrode regulation.

Briefly, in this system, the electrodes are attached to pistons actuated by hydraulic pressure; the flow of water is regulated by a valve which is operated by oil pressure on one side and by an opposing spring on the other. Any variations in the electrode current, caused by the state of the charge and the melting process, are reproduced in a movable magnetic core linked by a rod to a piston valve which controls the flow. To facilitate loading by means of a drop-bottom steel charge basket the roof is provided with lift and swing aside motions.

The motive power for operating the electrode movement, and for tilting the furnace body, swinging aside the roof and raising the furnace door, is supplied from a common hydraulic system. There are two electrically driven pumps (one being a standby) in the sump supplying water to the accumulator, to which a compressed air bottle is also fitted. The main function of the compressed air feed is to damp out any pressure oscillations that may occur during operation and to offer means of lifting the electrodes in the event of an electricity supply failure. Spring-loaded clamps hold the electrodes in position; unclamping is effected through an off-take from the hydraulic pressure system.

The furnace has a rating of 2000kVA, the power being taken from a 6·6kV supply through a transformer. We learn that the installation is designed to handle miscellaneous charges of mild steel scrap and turnings, for the ultimate production of high-quality castings. The electricity consumption is given as 650kWh per ton of steel melted, the average melting time being 2·16 hours with a 3-ton charge. Eight-inch diameter graphite electrodes are used and the consumption is stated to be 10 lb of electrode per ton of metal produced.



Three-ton arc melting furnace with hydraulic operation of the electrode feed and of the tilting and other mechanical movements

Bombay's Oil Refineries

THE Standard-Vacuum Oil Company's £15,000,000 oil refinery, which went on stream last July, was formally opened by the Union Production Minister, Mr. K. C. Reddy, on November 19th. The refinery is the first of two to be completed near Bombay; the other one is owned by the Burma-Shell Company and will probably be ready in six to eight months. The Standard-Vacuum refinery has been built in eighteen months, six months ahead of schedule. Most of the specialist work was under the supervision of the company's own engineers, and the rest, mainly civil and building work, was entrusted to Indian engineers and contractors. The refinery has a capacity of 25,000 barrels a day and will normally use crude oil from the Middle East. The Burma-Shell refinery will be about twice as big and cost about £20,000,000. When it goes on stream India will be self-sufficient as regards petrol, kerosene and most other petroleum products, which she has to import at present from hard currency areas.

The principal products and the approximate yields per year are: gasolene, over 90,000,000 gallons; kerosene, 40,000,000 gallons; automotive diesel oils, 18,000,000 gallons; industrial diesel oils, 40,000,000 gallons; industrial fuel oil, 55,000,000 gallons; and bunker fuel oil, 45,000,000 gallons,

Metallurgical Topics

American Society for Metals

ALTHOUGH many of the thirty-nine papers presented at the meeting of the American Society for Metals, held at Chicago on November 1 to 5, 1954, were of primary interest to workers in physical metallurgy, there were some having an immediate practical bearing on the treatment and properties of engineering materials. About half the papers referred to researches carried out on iron and steel and a brief reference to a few of these may be of interest.

STEELS : STRUCTURE AND PROPERTIES

There were several papers on hardenability (13, 14, 15),* including the calculation of hardenability, and on the structure of incompletely transformed martensitic areas, on continuous cooling transformations (33), and structural changes on tempering (21), and on the transverse properties of slack-quenched steel (24). In fatigue tests on 0·8 per cent carbon steel, supplemented by metallographic observations and measurements of the position of fracture, G. E. Dieter, R. F. Mehl and G. T. Horne (25) found that the pearlitic structure showed a lower fatigue limit and a smaller scatter, both in fatigue strength at a given number of cycles and in fatigue limit, than the spheroidised structure. They attributed the lower fatigue limit to the higher concentration of stress due to the carbide lamellæ in the pearlite. They also presented some evidence in support of the view that inclusions are the primary cause of the statistical scatter in fatigue properties. Because of the damage that can be produced by improper methods of grinding hardened steel, W. E. Littmann and J. Wulff (11) have investigated the effect of the heat which is generated in the grinding process, and found an approximate relationship between the grinding energy input and the peak temperatures reached within the work. They list, as mechanical factors which minimise the heat generated in grinding, decreased downfeed per pass, increased work speed, lubrication by the coolant, and a dressing technique which yields the sharpest wheel conditions consistent with finish requirements.

HARDENED STEELS

The tensile and impact properties of the martensite in quenched low carbon steels were studied by C. C. Busby, H. W. Paxton and M. F. Hawkes (9) in connection with the development of high-strength steels having better ductility and toughness at each of several tensile strength levels. It was found that steels containing 0·15 per cent of carbon or less had appreciable ductility in the as-quenched condition. After tempering at 100 deg. Cent., all tensile properties were better than those of steels containing a higher carbon, quenched and tempered to comparable tensile strength. The ratio of yield to tensile strength was relatively low (about 0·7), but could be raised, at some sacrifice of ductility and impact figure, by a suitable strain ageing treatment. The maximum attainable hardness was dependent on carbon content and was not affected by the addition of nickel or chromium or manganese, but nickel was most beneficial in lowering the transition temperature of tough to brittle fracture ; chromium up to 2 per cent also lowered the transition temperature somewhat, while manganese between 0·8 and 1·5 per cent or higher raised the transition temperature and to that extent damaged impact quality.

The maximum attainable hardness of the martensite obtained in steels containing 0·035 to 0·15 per cent carbon was shown by A. E. Nehrenberg, P. Payson and P. Lillys (16) to be a function of the nitrogen as well as of the carbon content, and to depend on these two elements only. It was not affected by alloy additions. For example, a variation in chromium content from 0·5 to 15·5 per cent in steels within this carbon range appeared to have no significant effect on the attainable hardness. It was suggested that an increase in maximum hardness previously observed in quenched 0·02 per cent carbon iron-chromium alloys with increasing chromium might have been due to nitrogen, which tends to increase with increasing chromium rather than to the chromium itself.

Attention was drawn to the low elastic limit of hardened steels in a paper by H. Muir, B. L. Averbach and M. Cohen (23).

EFFECTS OF STRESS AND DEFORMATION

There were several papers relating to the effect of deformation or cold working on the phase changes which occur in steels, or on the structural condition of the products of transformation. It is well known that plastic deformation causes a breakdown of unstable austenite, and that the imposition of stress during isothermal transformation increases the rate of austenite decomposition. This subject has been pursued by S. Bhattacharya and G. L. Kehl (22), who confirmed the acceleration of the rate of isothermal transformation by applied stress in 0·44 and 0·89 per cent carbon steels and in a nickel-chromium-molybdenum steel. Both the beginning and ending times of the austenite to bainite transformation were shortened by applied stress,

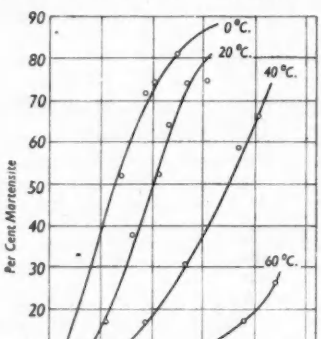


Fig. 1—Amount of martensite produced in 0·016 per cent carbon 18 : 8 chromium-nickel steel by plastic deformation at the temperatures indicated (30)

the greatest effect being produced by a stress of the order of the yield stress of the unstable austenite. Applied stress exceeding the yield stress of the austenite produced a marked orientation effect on the resulting structure. It was also observed that the effect of stress on the transformation of austenite persisted even when the applied stress had been removed. The applied stress was most effective in accelerating the transformation when it was applied to the austenite after a lapse of time equivalent to the beginning of transformation under no stress.

Similar effects of deformation were observed in 18 : 8 chromium-nickel austenitic steels containing 0·006 to 0·127 per cent of carbon by H. C. Fiedler, B. L. Averbach and M. Cohen (30). A portion of the austenite can be transformed to martensite by plastic deformation or by cooling to sub-zero temperatures. They found that the amount of martensite produced by plastic tensile strain increased as the temperature of deformation was lowered (Figs. 1 and 2). Small amounts of plastic strain in the austenite at atmospheric or higher temperatures had a stimulating effect on subsequent transformation during cooling to sub-zero temperatures, the maximum stimulation being attained after elongations of 2 to 4 per cent (Fig. 3). Mechanical stabilisation or complete suppression of the transformation during cooling was achieved by large elongations. Increasing amounts of deformation were required to achieve mechanical stabilisation as the carbon content was decreased, for example, nearly 40 per cent elongation when the carbon was 0·016 per cent, but under 20 per cent with 0·058 per cent carbon, as shown in Fig. 3.

These results should be considered in conjunction with those in a recent Carnegie Scholarship Report by B. Cina,† who dealt with the effect of cold work at room temperature and below on the martensite transformation in several austenitic chromium-nickel steels of varying nickel and chromium content.

Another study of the influence of deformation upon a phase change was that of A. J. Lena and W. E. Curry (27) on the effect of cold work

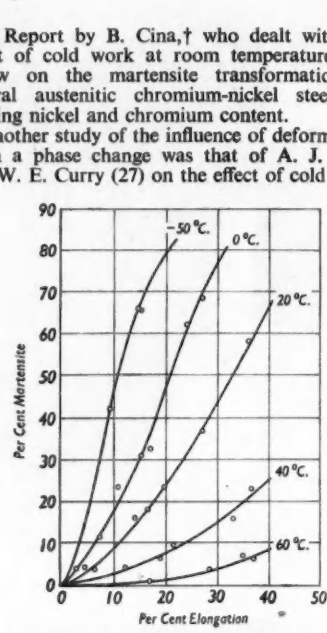


Fig. 2—Amount of martensite produced in 0·058 per cent carbon 18 : 8 chromium-nickel steel by plastic deformation at the temperatures indicated (30)

and recrystallisation on the formation of the sigma phase in highly stable austenitic stainless steels. They found that the accelerating effect of cold work on the rate of formation of sigma was not simply to produce more nuclei of sigma which grow after recrystallisation, but that recrystallisation was essential if pronounced acceleration of sigma formation was to take place. A small amount of cold work may have a retarding effect, and if the amount of cold work was less than that required for recrystallisation at a given temperature, the accelerating effect was small or non-existent.

DUCTILE CAST IRON

Quenched structures of fully austenitised ductile cast iron consist of primary spheroids of graphite dispersed in a matrix of martensite. Subsequent tempering treatments that decompose the martensite produce a large quantity of secondary graphite in the form of fine graphite

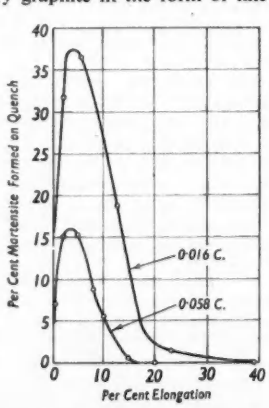


Fig. 3—Amount of martensite formed by first elongating at 93 deg. Cent. and then cooling to −195 deg. Cent. for fifteen seconds. No martensite was formed during the elongation (30)

spheroids. J. C. Danko and J. F. Libsch (32) investigated the formation of this secondary graphite and concluded that the martensite produced by quenching breaks down on tempering into ferrite and a silicon-rich carbide which decomposes on heating at 650 deg. to 700 deg. Cent., with the formation of fine graphite spheroids. Increase in the silicon content of the ductile iron resulted in greater quantities of secondary graphite, whereas carbide-forming

* The figures in brackets refer to the number of the American Society for Metals, 1954, preprint.

† *Journal of the Iron and Steel Institute*, August, 1954, page 406.

elements appeared to reduce the amount of the fine graphite spheroids.

The properties of the ferritic, pearlitic and high-alloy austenitic ductile cast irons at elevated temperature were determined by C. R. Wilks, N. A. Matthews and R. Wayne Kraft, Jr. (34). In short-time tests the properties of the pearlitic iron were superior to those of the ferritic grade, but above 425 deg. Cent. the pearlite gradually breaks down, giving a ferritic iron which has lower creep strength than the standard ferritic grade, the creep strength of which is comparable with that of low-carbon steel. Markedly higher hot strength at 540 deg. Cent. was obtained with the high-alloy austenitic grade.

Other Papers

Many of the non-ferrous papers were concerned with constitutional diagrams of alloy systems, but there were a number dealing more generally with non-ferrous subjects, such as the stress corrosion of magnesium alloys (18), the heat-treatment of a wrought cobalt-base alloy (Stellite 21) having high-temperature applications (39), and the properties of zirconium and some of its alloys (5, 37).

Elastic Limit of Hardened Steels

The elastic limit and yield behaviour of hardened steels containing 0·20, 0·41 and 0·82 per cent of carbon has been studied by H. Muir, B. L. Averbach and Morris Cohen[1] by the aid of sensitive electrical resistance strain gauges used to detect the onset of a permanent change in the length of the test specimen on unloading from successively higher stresses. The elastic limit was defined as the stress above which progressive permanent deformation occurs on repeated tensile loading. Occasionally negative residual strains (of the order of 20×10^{-6}) appeared after loading below the elastic limit and unloading. In such cases the elastic limit was defined as the stress above which the residual strain continued to increase towards the positive direction. These negative strains were probably associated with the presence of internal stress, but the phenomenon was not sufficiently reproducible to permit definite conclusions. Cyclic loading was increased progressively until a residual strain of 0·2 per cent was reached. The elastic

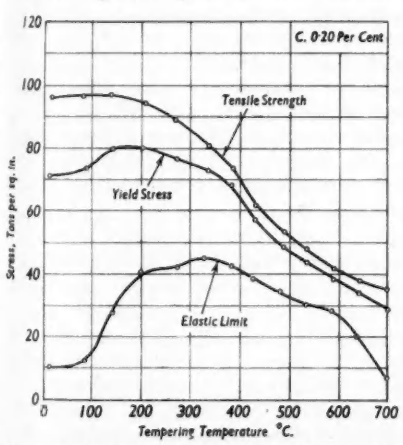


Fig. 1—Mechanical test results for steel containing carbon 0·20, manganese 0·89 per cent, quenched from 910 deg. Cent. in 10 per cent brine and tempered (Muir Averbach and Cohen)

limit and other tensile properties were studied as a function of the tempering temperature. The 0·2 per cent yield, tensile and fracture strengths usually fell off with decreasing hardness, unless premature brittle fracture had taken place ; but the elastic limits are low even when the hardness is high. A large number of curves of stress against residual strain for different tempering temperatures are given, and the results are summed up in three diagrams, small parts of which are reproduced in Figs. 1–3. In the tests represented by these, the steels were quenched from the tempering temperature. If they were air cooled the elastic limits were somewhat higher, other tensile properties being unaffected. Elongation and reduction of area, which were low in the fully hardened 0·20 per cent carbon steel and nil (owing to brittle fracture) in those containing higher carbon, showed marked improvement in specimens tempered at about 350 deg. Cent. and above.

The general character of these curves has been well known for a long time if limit of proportionality is taken as an equivalent of elastic limit. Similar curves were published by Dr. Aitchison,[2] who also demonstrated the improvement in proportional limit produced by tempering ; but this behaviour has often been overlooked and its practical implications ignored. The present authors recognise that the low limit of proportionality hitherto assigned to hardened steels, and the effect of tempering on them, bear a close relation to the results shown in their own curves for elastic limit against tempering temperature ; and they also point out the similarity in

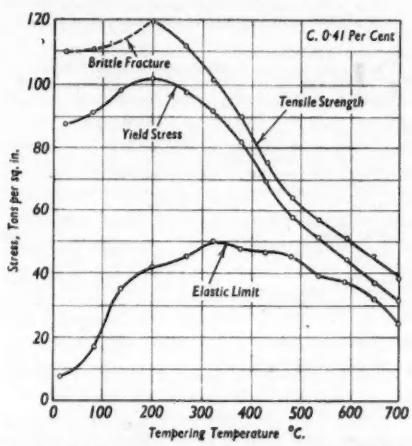


Fig. 2—Mechanical test results for steel containing carbon 0·41, manganese 0·72 per cent, oil hardened (0·252in diameter) from 845 deg. Cent. and tempered (Muir, Averbach and Cohen)

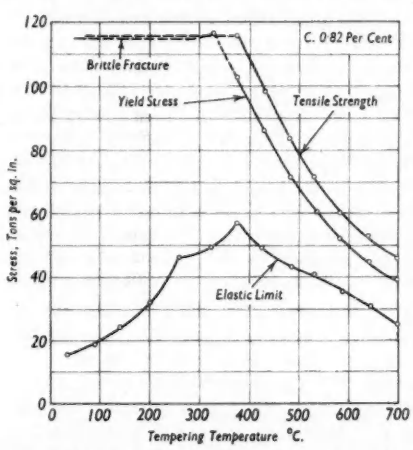


Fig. 3—Mechanical test results for steel containing carbon 0·82, manganese 0·84 per cent, oil hardened (0·252in diameter) from 845 deg. Cent. and tempered (Muir, Averbach and Cohen)

proportional limit of cold-drawn steels and the beneficial effect of tempering. High elastic limits are not necessarily obtained at high strength and hardness levels. As a practical conclusion, the authors point out that this fact may be of some importance in spring and bearing applications, in which permanent set has been observed after repeated loading at stresses well below the engineering yield strength. A five-fold increase in elastic limit may often be obtained by tempering at 260 deg. to 370 deg. Cent. Furthermore, the relatively low ratio of elastic limit to yield strength in steels which have received only a slight tempering may become a significant limitation in the development of very high-strength steels.

References

1 American Society for Metals, Annual Convention, 1954, Preprint No. 23.
2 Iron and Steel Institute, Carnegie Scholarship Memoirs, 1923, Vol. 12, page 113 ; *Trans. Amer. Soc. Steel Treating*, 1924, Vol. 5, page 491.

Hydrogen Embrittlement of Titanium Alloys

Brittle failure of a complex ($\alpha+\beta$) titanium alloy component at the Wright Air Development Centre in the U.S.A., and the possibility that it was due to hydrogen embrittlement, have led to further investigation of the effect of hydrogen on the tensile ductility of this alloy.* The material in question was a titanium alloy containing 3 per cent of manganese with 1 per cent of each of the elements iron, chromium, vanadium and molybdenum. For the purpose of the investigation, it was rolled at about 845 deg. Cent. down to $\frac{3}{4}$in diameter, annealed at 780 deg. Cent. and rolled to $\frac{1}{4}$in round. After water quenching from 700 deg. Cent., ageing for eight hours at 480 deg. Cent. and cooling in air, the tensile strength was about 75 tons per square inch. Specimens were charged with hydrogen to the extent of 30, 120, 200 and 300 parts per million, and tensile tests were made with test pieces of 0·250in diameter at −77, 25 and 90 deg. Cent. and three different rates of straining, 0·5in, 0·05in and 0·005in per minute.

The maximum load was but little affected by hydrogen content or by rate of strain, but at any given rate of strain the reduction of area was reduced by increasing the hydrogen content. The relation between hydrogen content, rate of strain and reduction of area in tensile tests at room temperature is shown in the following table :—

Rate of strain, inches/minute	Reduction of area, per cent : hydrogen content, p.p.m.			
	30	120	200	300
0·5	50	40	38	14
0·05	48	35	13	5
0·005	46	25	8	4

The effect of reducing the rate of strain was very marked and increased with increase in hydrogen content. The embrittling action occurred during necking, after the maximum load in the tensile test had been reached ; the rate of deformation beyond the maximum load was the effective factor.

Powder Metallurgy

In view of the forthcoming symposium, organised by the Iron and Steel Institute in association with the Institute of Metals, attention may be directed to a series of articles on recent advances in powder metallurgy, which appeared in *Iron Age* for September 30, 1954. Apart from the unique character of powder metal technique in dealing with metals of very high melting point and in the fabrication of parts from materials of widely different physical characteristics (e.g. copper and tungsten, bronze and graphite, metals and ceramics, &c.), powder metallurgy is steadily gaining recognition as an economic method of production of many metal components which would otherwise have to be made from forgings or castings.

In response to the demand for a wider range of products, modern powder metal presses are designed for producing larger and more complex parts, and a very large amount of work has been carried out on the principles and technique of compacting and sintering. Modern sintering furnaces, with protective atmospheres and accurate control of temperature, help to ensure high quality in the product. Porosity of powder metal compacts, for some purposes an advantage, can be varied to suit conditions of service. By hot coining operations porosity can be eliminated and the true density of the solid material attained. Hot coining of nickel-molybdenum steels to full density is described, and preliminary results with high-temperature resisting alloys are said to be encouraging. Parts so produced are as good as or better than cast parts of the same material, and heat-treatment may be applied to them to develop the required properties. Surface finish may be improved, for many purposes, by electroplating. Porosity of the surface, if not removed by coining, rolling or pressing, is reduced by buffing. Copper is deposited to a thickness of about 0·001in. This layer is buffed and electroplated successively with nickel and chromium.

* R. J. Kotfila and E. F. Erbin, *Metal Progress*, October, 1954, page 128.

THE ENGINEER

Vol. 198 NOVEMBER 26, 1954 No. 5157

LEADING ARTICLES—
Guided Missiles ... 742
Two-Stroke Oil Engines ... 742

ARTICLES—
Agricultural Machinery Manufacturing Developments ... 727
Air-Cooled Diesel Engines. (Illus.) ... 738
Arc Furnace with Hydraulic Electrode Feed. (Illus.) ... 739
Bombay's Oil Refineries ... 739
Boundary Layer Control. No. II. (Illus.) ... 751
Coal Preparation Plant at Mansfield Colliery. (Illus.) ... 747
"Comet" Court of Inquiry ... 725
Engine and Propeller Overhaul Life. (Illus.) ... 749
Engine Testing Plant. (Illus.) ... 746
Free Gold Extraction from Pulped Ore ... 753
Genesis of the Thermionic Valve ... 745
Graduates in Industry ... 725
Guided Missiles. No. I. (Illus.) ... 728
Indian Steel Plants ... 737
Interim Road Improvement Schemes in London 725
Iron and Steel Institute. No. I ... 735
Marine Main Steam Control Unit. (Illus.) ... 753
Mechanical Engineering as a Profession ... 725
Ministry of Transport Marine Survey Service ... 725
Radio Compass for Civil Aircraft. (Illus.) ... 737
Supervisory Equipment for Steam Turbine Shafts ... 725
Testing the Performance of Precision Ball Bearings. (Illus.) ... 732
Thread Inserts. (Illus.) ... 726
Two Small Marine Diesel Engines. (Illus.) ... 750
1½ Million Volt Impulse Generator. (Illus.) ... 748

AMERICAN SECTION—
Materials Testing Reactor of the U.S. Atomic Energy Commission. No. II. (Illus.) ... 755
Adoption of the International Nautical Mile ... 756

METALLURGICAL TOPICS—
American Society for Metals. (Illus.) ... 740
Elastic Limit of Hardened Steels. (Illus.) ... 741
Hydrogen Embrittlement of Titanium Alloys ... 741
Powder Metallurgy ... 741

LETTERS TO THE EDITOR—
The Engineers' Tide ... 744
Broad Flange Beams ... 744

LITERATURE ... 744
Books Received ... 744
Short Notices ... 744

OBITUARY—
George Bransby-Williams ... 743
Lieut.-Colonel P. J. Cowan, M.B.E. ... 743

NEWS AND NOTES—
African Engineering News ... 749
British Patent Specifications. (Illus.) ... 759
British Standards Institution ... 734
Catalogues ... 760
Contracts ... 758
Forthcoming Engagements ... 760
Industrial and Labour Notes ... 757
Notes and Memoranda ... 758
Personal and Business ... 758
Technical Report ... 750

GUIDED MISSILES

However much military exercises may be designed to reveal the tactical effects of new weapons and the best means of using them only the test of war itself can reveal whether peacetime reasoning about them is correct. Repeatedly war has brought surprises. Who in 1914 foresaw that improvements in machine guns would condemn armies to the stalemate of trench warfare? Did not naval experts at the same date expect sea actions to be fought at ranges of no more than a very few thousand yards? In 1940 the Germans themselves seem to have been taken by surprise by the success of their armoured tactics! How difficult then it must be for military minds to-day to assess at all accurately how the next war will be fought. Perhaps the consequences of the use of "atomic" artillery can be estimated with some precision. But what will be the effects of the use of guided weapons of almost untried potentialities? How deeply will those weapons influence land warfare? Ought new warships to be equipped with guns capable of discharging atomic shells; or ought rocket projectors to be their armament? How deadly will ground-to-air missiles prove? Will the bomber of the future have any chance of reaching its target unscathed? What will be the consequences upon the development of tactics and strategy? These are the questions the military expert has to try to answer, knowing, depressingly, how probable it is, if history is to be trusted, that his guessing will be proved at least partially wrong by events.

But for engineers the situation created by the advent of new weapons is different and very much simpler. For, to them the construction of a guided missile is an exercise not in war but in technical design. The fact that the "payload" of the vehicle is an explosive; and that the purpose of the missile is to explode upon a close approach to or contact with its target is, maybe, of much significance to its user, but of no great technical interest to its maker. The technical problem lies in the construction and, above all, in the control of the missile, whereas to make it explode once the target has been approached or reached is relatively simple. It was in fact with no special interest in hearing about a new weapon, as such, that a large audience gathered last Friday at the Institution of Mechanical Engineers to hear Mr. Gardner deliver a James Clayton lecture on "Guided Missiles." It was much more in the expectation that there would be a great amount of technically interesting material to hear about that they came together. In the result, as will be seen from the extracts we print on another page, their hopes were not fully realised; for the demands of secrecy severely limited what Mr. Gardner was permitted to reveal. Yet though Mr. Gardner was able to say almost nothing about the design of actual missiles he was able to talk about some of the fundamental principles involved, and to refer to a few of the difficulties of applying them. Electronics, though the part it plays in controlling flight is essential, he hardly touched upon. But he did mention the effects of kinematic heating, show how high must be the accelerations of a missile if it is satisfactorily to home upon a target taking evasive action, describe the special characteristics for particular purposes of differing means of propulsion, and emphasise strongly the complexity of the problem of designing satisfactory aerodynamic controls. He remarked significantly "It is becoming apparent that the guided missile is a complex servo-loop in which the reaction of the function of every component is felt through the loop and into which much spurious and disturbing information is injected, for example, by aero-elastic effects, radar 'noise,' and movement of the target."

But how very much more information Mr. Gardner could have provided if he had been allowed! For, unquestionably, researches must have gone very much further in this country and at Woomera and in the United States than the lecture revealed. In the United States we know, and we may justifiably guess here also, weapons similar to the American "Nike" ground-to-air missile are already in production. The Russians, too, are known to be little if at all behind the Western powers in designing and making similar weapons. In these circumstances may it not justifiably be asked what object technical secrecy is now designed to serve? The damage done by it is obvious enough. In their desire to prevent technical information reaching an enemy security people, we think, forget, that by secrecy they deny to their own research teams the salutary discipline of having their work criticised by equally talented men working in related but non-secret fields; that they prevent the members of those teams entering into those more intimate private discussions between individuals that do so very much to improve techniques; that they discourage the more brilliant and coming younger men from engaging in studies and researches within that field because of their doubt that the work may already have been done under the seal of secrecy or a fear that publication of the results will not be permitted; and that by keeping researches secret they deny to industry in general, knowledge likely to prove applicable in other fields and which may well trigger-off other advances of use in war. It is, indeed, an inevitable consequence of technical secrecy that it hampers and delays advance; particularly must it do so in the development of so complex a device as a rocket weapon into whose design there must enter metallurgical, chemical, mechanical, electronic, aerodynamic and production engineering considerations. A more open treatment of the complex technical problems involved would, we believe, lead to a much higher rate of advance; and to the design and construction by this country of weapons superior to those of any potential enemy.

TWO-STROKE OIL ENGINES

There exists a widely spread impression that what is called the "two-stroke" engine came into existence in comparatively recent times. It is true, of course, that the entire history of the internal combustion engine is covered by the last century and a half. It is also true that the earliest internal combustion engines—which were of the atmospheric type—gave a working stroke at each revolution. One hundred and fifty years have passed since Philippe Lebon d'Humbersin received grant of his patent relating to "La construction des machines mues par la force expansive du gaz." Progress might have been faster had not Lebon d'Humbersin been murdered in what is now the Champs Elysées, after which tragic event the atmospheric engine marked time until, during 1825, Samuel Brown developed what has been recognised as the first gas engine which ever accomplished actual industrial work. After Brown's time the atmospheric gas engine—completely overshadowed by the steam engine—made comparatively little

progress until Lenoir in 1860 and Langen and Otto in 1864, demonstrated its commercial possibilities. The first mention of the four-stroke engine is by Beau de Rochas in 1862, but it was not until 1876 that Gasmotorenfabrik Deutz applied for the German patent covering the Otto four-stroke gas engine. The success of this engine was immediate and momentous, one of the benefits flowing from it being the challenge offered to inventors eager to produce gas engines which did not infringe the strongly held Otto patents. That is why there appeared in Great Britain, during 1878–1879, a veritable crop of two-cycle engine patents such as those applied for by Atkinson, Benz, Clark, Linford, Robson, Williams and others.

The above remarks are suggested by perusal of a paper, "Notes on the Performance of Some Two-Stroke Oil Engines," read on November 18th before the Diesel Engine Users Association by Professor S. J. Davies and Mr. M. A. Plint. This paper is directed chiefly to the influence of scavenging and to methods of assessing scavenging efficiency. That effective scavenging is of major importance in the internal combustion engine was recognised—perhaps for the first time—by Barnett, who, in his patent of 1838, describes an arrangement intended "to draw off from the cylinder, during the descent of the piston, the products or any portion of the unconsumed gas which may remain after the explosion of the mixture has taken place." Long after the date of Barnett's patent, Mr. Justice Pearson (in the case of Otto *v.* Steel in 1885–6) remarked that whereas Otto desired to retain the "residuum," Barnett desired to get rid of it. In their interesting paper, Professor Davies and Mr. Plint dealt with ten different two-stroke engines having cylinders ranging from 2·75in by 4in to 13·39in by 22·44in, the speeds ranging from 300 r.p.m. to 2800 r.p.m. The means of scavenging described include piston, Roots blower and centrifugal blower. Looking at the sectional views of the various small engines and taking particular note of the number of fuel injections—they range up to forty-seven per second per cylinder—we may feel how fortunate it is for the designers of two-stroke engines that the piston should be standing still while the crank is racing over the bottom dead centre! If we calculate on the time per degree of crank angle when the engine is making, say, forty-seven revolutions per second, we get an idea of the fraction of a second during which the scavenging and charging of a two-cycle engine must be accomplished. Such reflections will cause us to admire the courage and ingenuity shown by the designers of small two-cycle engines, handicapped as they are by the fact that the smaller and faster the engine, the greater become the fluid-pumping losses. Writing on this very point in his book, *The High-Speed Internal-Combustion Engine*, Sir Harry Ricardo remarks that "the pressure required to force at every cycle a given weight of air through a port or valve of given size increases as the square of the speed, and the power expended as the cube of the speed." *Natura nihil agit frustra* is said to be the only undisputed axiom in philosophy, and certainly the problem in the scavenging of the two-cycle engine is to charge the cylinder with the maximum weight of oxygen consistent with the simplest design of engine and the minimum of work in pumping the scavenging air.

There is about small engines something which appeals very much to the popular imagination. Long ago Sir Thomas Browne asserted — characteristically — that "Ruder heads stand amazed at those prodigious pieces of Nature, whales, elephants, dromedaries and camels; these, I confess, are the colussus and majestick pieces of her hand; but in these narrow engines there is more curious mathematicks." Certainly there is much to interest and instruct us in the constant evolution of small internal combustion engines, but a consideration never to be lost sight of is the fact that the most important thing about any engine intended for commercial service is its endurance expressed in hours of trouble-free running between overhauls. Where the object of the design is to reduce weight and dimension by increasing the speed and/or the b.m.e.p., it is not realistic to suppose that there will be no sacrifice of endurance. Experience shows that large slow-speed, two-cycle engines of various established makes will give trouble-free service over many years with notably long periods between major overhauls and conspicuously low lubricating oil consumption. In the case of small two-cycle engines, the hours of running required per year may be comparatively few whether the engines are used for automobile or for agricultural tractor service. In an industrial engine, where the running hours per year are out of all proportion higher, the problem of the designer is to ensure the highest degree of durability combined with the lowest operating cost. In both groups there is an ever-growing need for accessibility and simplicity and this may press harder on the manufacturer of the small engine. Specialisation of function is a principle to be kept in mind, and there must always be scope for a variety of engines. Professor Davies and Mr. Plint have described some of these varieties and it is to be hoped that there may be a response to their request for that information as to long-term performance which can only be provided by the engine user.

Obituary

GEORGE BRANSBY-WILLIAMS

We have learned with regret of the death of Mr. George Bransby-Williams, which occurred on November 17th. Mr. Bransby-Williams had a long and varied career as a civil engineer, principally in the subjects of water supply and sewerage and he was an authority particularly on the hydrological aspects of reservoir design. He was born in 1872, and received his scientific training at Clifton College. Subsequently he served a pupilage with Wright Butler and Co., engineers, and with Mr. James Mansergh. He became an associate member of the Institution of Civil Engineers in 1897 and a full member in 1909. His early experience included work on a considerable number of water supply and drainage schemes throughout the country, including, for instance, the Birmingham aqueduct. He was also concerned with railway civil engineering, gaining experience of such work in South Wales, and in South Africa, during the Boer War, when he served on the staff of the director of railways of the South African Field Force. In the years 1906–'08 he was consulting engineer to the Crown Agents, and in 1908 he became chief engineer of the public health department of the Government of Bengal, a post he held until 1927. His colonial work included designing and carrying out a scheme for the main drainage and water supply of Nairobi, and during his tenure of office as chief engineer in Bengal he carried out about seventy schemes, the most important of which were the Dakka main drainage, Goya water supply and Tittaghar main drainage schemes.

In 1927 Mr. Bransby-Williams again became a consulting engineer, in partnership with Mr. F. C. Temple. His work was still concentrated in India, and the larger schemes with which he was concerned as a consultant included the Jheria coalfields water supply, Rangoon water supply, Nagpur water supply, and the Lucknow and Cawnpore railway settlements sewerage and sewage disposal schemes.

During the course of his career he presented several papers to the Institution of Civil Engineers and contributed to discussion. His work in India, for instance, gave rise to the paper "Rainfall Off-flow and Storage in the Central Provinces, India," which was published in 1931. He was also a valued contributor to this journal, his most recent article being "Flood Intensities and Frequencies on British Catchments," which was published in The Engineer of August 22, 1952. He was the author of "The Flow of Water in Pipes, Sewers and Channels; over weirs and off catchments," and of "Storage Reservoirs." The latter volume, which was published in 1937, is very general in its scope, and the last chapter, "An Engineer's Odyssey," describes a tour through Britain visiting many famous hydraulic engineering works.

LIEUT.-COLONEL P. J. COWAN, M.B.E.

In our last issue we recorded briefly the death of Lieut.-Colonel Percy John Cowan, which occurred on November 15th at his home at Cranes Park, Surbiton, Surrey. Lieut.-Colonel Cowan, who was seventy-eight, was joint editor of our contemporary, *Engineering*, from 1924 until he retired in 1938.

Percy Cowan, who was the third son of the late Dr. T. W. Cowan, was educated at Rugby School and at University College, London. He served an apprenticeship in the Doncaster locomotive works of the former Great Northern Railway until 1899 and afterwards he continued for three years or so in the service of the G.N.R. During that time he made two visits to America to inspect locomotives, much of the experience gained undoubtedly forming the basis of a paper on "American Locomotive Practice," which he presented to the Institution of Civil Engineers in 1903. For that paper Cowan was awarded a Telford Premium and a George Stephenson gold medal. In December, 1903, Lieut.-Colonel Cowan was appointed assistant to the chief mechanical engineer of the Egyptian State Railways. Three years later he joined the editorial staff of *Engineering*, on which he served for thirty-two years apart from his years of military service, in the first world war. He was with the Mesopotamian Expeditionary Force, with the Royal Engineers, and later with the Railway Directorate, being mentioned in dispatches. In 1919 Lieut.-Colonel Cowan took part in the Afghan campaign with the North-West Frontier Force. He was awarded the M.B.E. in 1920. The second world war started

soon after Lieut.-Colonel Cowan's retirement from *Engineering* and for the greater part of it he was fully occupied as Army welfare officer for the County of Surrey.

Lieut.-Colonel Cowan was elected to associate membership of the Institution of Civil Engineers in 1903 and transferred to full membership in 1927. He had been a member of the Institution of Mechanical Engineers since 1904, and in collaboration with Mr. F. H. Trevithick presented a paper, in 1913, on "Some Effects of Superheating and Feed-Water Heating on Locomotive Working," in respect of which the eighth award of the Willans Premium was made.

But, probably, Lieut.-Colonel Cowan's greatest service to the Institution of Mechanical Engineers and to his fellow men was performed almost in secret. Only those who served with him on the committee of the Benevolent Fund of that Institution can have a full conception of the amount of work he put into a job very close to his heart. He served repeatedly as deputy-chairman, presiding in that capacity over committee meetings; and in or out of the chair he wielded a great and beneficent influence over its deliberations, through his common-sense, wisdom, the sincerity of his humane regard for the interests of those supported and helped by the Fund, and the understanding he so often demonstrated of human nature.

Literature

The Structure of Metals and Alloys. By W. HUME-ROTHERY and G. V. RAYNOR. London: The Institute of Metals, 4, Grosvenor Gardens, S.W.1. Price 35s.

THIS book is the third edition of the Institute of Metals Monograph No. 1, first published under the authorship of Dr. Hume-Rothery as a slender volume in 1936. Since then, in many reprintings, it has been a guide to students and an inspiration to many junior research workers. It was notable for the original generalisations with which the author's name was associated. These have withstood the test of time and so remain as part of the new edition, which, however, has been extended to cover a wider field without encroaching on the subject-matter of other books or introducing mathematical complications.

The book consists of seven parts. The first five, dealing with the electronic background, crystal structures, atomic radii, solid solutions and intermediate phases, though expanded to almost double their length, retain their original form. Substantial additions have been made in the form of new sections on defect structures in solid solutions, ternary solid solutions, relationships between the lattice spacings of solid solutions, and on that generally unwelcome constituent, the sigma phase.

A notable addition which adds greatly to the value of the book is Part 6 on the structure of the alloys of iron. This part, illustrated by some excellent optical and electron micrographs, contains a discussion of the form of the equilibrium diagrams of iron with other elements and especially of the implications of the iron-carbon equilibrium in carbon steels and alloy steels. There is a clear account of the phases and constituents produced by the decomposition of austenite, and ambiguities in current terminology are pointed out. There has, for many years, been no excuse for the confusion which still sometimes occurs between the products of the direct decomposition of austenite and those formed by the tempering of martensite. The sequence of constituents produced from austenite by gradually diminished rates of cooling and by isothermal decomposition at progressively lower temperatures is clearly described. There is also a brief account of the constitution of cast iron, with special reference to the form of the graphite.

Part 7, also, dealing with imperfections in crystals and deviations from the ideal lattice, is virtually new. It has been completely rewritten in the light of developments which have taken place in recent years. Eight pages in the 1936 edition have now become sixty-three and in addition there are some excellent photomicrographs. Polygonisation, lattice vacancies and the numerous aspects of the theory of dislocations are a few of the subjects touched upon in this concluding part of the book. All those who have benefited from earlier editions will welcome the opportunity of bringing their knowledge up to date, and to new readers the book can be strongly recommended as giving an accurate, concise and readable account of some of the most important advances in the science of metals.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE ENGINEERS' TIDE

SIR,—As a past student of the Post Graduate School of Applied Mechanics at Sheffield University, I should like to comment on the recent article entitled "The Engineers' Tide," by Mr. A. C. M. Sigsworth.

The young graduate engineer, entering industry for the first time, can become a sadly disillusioned and soured person if he fails to appreciate that a university education is but a stepping-stone on the way to mature engineering experience. The blame for industry's suspicion and even hostility towards graduates, can be laid at the feet of those many "fortunate" young men who enter industry assuming that they "know it all." They believe they have a mission in life to teach the "ignorant," rather than augment their purely theoretical knowledge by that know-how acquired only after several years of industrial experience.

There is an old proverb which postulates that it is better to say nothing and appear ignorant than speak and confirm ignorance. If the graduate adopts this sort of attitude, his higher education offers him the unique advantage of being able to differentiate between sound and unsound advice.

On the other hand, the graduate can, very easily, become frustrated and wonder whether his scholastic training has any lasting value. Without the opportunity to practice that fundamental knowledge acquired during a degree course, there is little wonder that much is forgotten and many opportunities lost.

Post graduate courses fulfil two basic requirements; first, they give the graduate with some years in industry (and post graduate courses are intended primarily for such people) renewed faith in his basic teachings and ability to think critically; and, secondly, they offer up-to-date knowledge (particularly to the specialist engineer whose thinking is consequently narrow) in a wide variety of matters which have developed since his university days.

Industry also benefits in that knowledge and experience go hand in hand. Additional knowledge develops latent experience and the industrial engineer must, if he is ever to attain executive level, study, criticise and develop, to the benefit of industry generally, new techniques. The post graduate schools are doing much to satisfy the need for continued education beyond graduate level, a need which is not only very real if we are to become "the idea shop of the world," but which also helps the potentially able engineer to attain a higher level of technical ability.

G. D. JORDAN

Sheffield,
November 20th.

BROAD FLANGE BEAMS

SIR,—Mr. Skelton's letter in your last issue pointed out the primacy of the Grey mill at Differdange over the first mill of this type put down by the predecessors of the Bethlehem Steel Company at their Saucon plant. He also alluded to the undisputed advantages of this product, but did not mention that on the Continent a considerable tonnage of broad flange beams is produced on ordinary heavy section mills with simple modifications. This tonnage probably approximates to the combined output of the two universal beam mills at Differdange and Peine. This practice was successfully introduced into this country by one of the leading producers of structural shapes in 1946 who can now offer a useful range of these sections.

It might be asserted that the smaller sizes of beams can be more conveniently rolled on a conventional mill, and it is only over say, a 20in by 12in beam that the universal mill, with all its complications, would be preferred.

As to the price angle, it is doubtful if any substantial extra—over the corresponding R.S.J. price—is justified by reason of the enhanced manufacturing cost for beams. If suitable ingots are employed the "yield" need not be less than for conventional joists, and all time expenses are favourably influenced by the large output possible when rolling beams; the power cost is also lower. On the other hand, roll costs tend to be greater in both ordinary and universal mill practice and straightening costs are up slightly. Any extra charged for these products is thus dictated primarily by commercial policy.

G. A. V. RUSSELL, M.I.C.E.

Saltburn-by-the-Sea, Yorks,
November 22nd.

Short Notices

Production Tooling Equipment: The Design of Jigs, Tools and Gauges. By S. A. J. Parsons, B.Sc., M.I.Mech.E., M.I.Prod.E. London: Cleaver-Hume Press, Ltd., 31, Wright's Lane, W.8. Price 25s.—The subject matter in this book is based upon lectures delivered to advanced students studying for the Higher National Certificate or the associate membership examination of the Institution of Production Engineers. The chapters of the book fall broadly into main sections dealing in detail with drilling jigs and fixtures, cutting tools and tool layouts, and gauges. Each subject is dealt with in a clear practical way, and is illustrated by diagrams and drawings. In addition to providing a useful reference work on modern practice for students and apprentices, this new book will be read with interest by those concerned with tooling for production work.

Books Received

Growth of Mechanical Power. By Miles Tomalin. London: Methuen and Co., Ltd., 36, Essex Street, W.C.2 Price 8s. 6d.

Timestudy for Cost Control. Third edition. By P. Carroll and C. D. Dyer. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 40s.

The Dynamics and Thermodynamics of Compressible Fluid Flow. Vol. 2. By A. H. Shapiro. U.S.A.: The Renold Press Company, 15, East 26th Street, New York 10, N.Y. Price 16 dollars.

Elements of Electrical Machine Design. Third edition. By A. Still and C. S. Siskind. London: McGraw-Hill Book Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 72s.

Industrial Stoichiometry. Second edition. By W. K. Lewis, A. H. Radasach and H. Clay Lewis. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 60s.

Genesis of the Thermionic Valve

By Professor G. W. O. HOWE, D.Sc., LL.D., M.I.E.E.

As reported briefly in our issue last week, the Institution of Electrical Engineers held a special meeting in London, on Tuesday, November 16th, to celebrate the jubilee of the thermionic valve. At this meeting the development of the thermionic valve up to the present day was traced in a series of three lectures. Abstracts from Professor Howe's lecture are reproduced below.

IN 1879, whilst Fleming was still at Cambridge, he had been appointed scientific adviser to the Edison Telephone Company, which was involved in litigation with the Government. Three years later, in 1882, having left Cambridge, he was appointed "electrician" to the Edison Electric Light Company, of which John Hopkinson was the scientific adviser. In those days the word "electrician" had quite a different meaning! In 1884 he went to America to discuss with Edison the difficulties of the electric lighting industry in England, largely due to restrictive legislation. This close link between Fleming and Edison is of importance in connection with the thermionic valve. As the British Association meeting that year was in Montreal, he took the opportunity of going to the meeting, and he visited many of the cities of Eastern Canada. He then returned to New York and made a thorough investigation of the electric lighting industry in America, which he embodied in a report to his directors on his return to this country.

Five years before this, in 1879, Edison had obtained a British patent for a carbon filament lamp of high resistance. In 1884, the year of Fleming's visit to him, Edison exhibited at Philadelphia an interesting discovery which he had made the year before. He had fixed in the bulb of a carbon filament lamp a metal plate carried by a platinum wire sealed through the wall of the bulb. He found that if the metal plate was connected through a galvanometer to the positive terminal of the filament the galvanometer showed that current was flowing, but if the connection was made to the negative terminal no current was indicated. This phenomenon was subsequently known as the Edison effect.

Edison made practical use of the device, but not for telegraphy. He connected the lamp filament with a suitable adjusting resistance across the mains in the power station. When the voltage between the mains had the correct value the filament had a certain temperature and the current flowing through the galvanometer was indicated by its pointer. If the voltage between the mains increased above the normal value, the brightness of the filament, and with it the current through the galvanometer, increased. Conversely, if the mains voltage fell below the normal, the galvanometer current decreased. The pointer of the galvanometer was made to operate as a relay and rectify any variation of voltage from the normal value. It had nothing to do with telegraphy, but was simply used to regulate the voltage in the power station and maintain it constant.

The Edison effect greatly interested Fleming, and he got the Edison Swan lamp works to make him a number of lamps with the metal plate of different sizes and shapes and in different positions with respect to the carbon filament. From his experiments he came to the natural but erroneous conclusion that atoms of carbon carrying a charge of negative electricity were responsible for the current through the vacuum, but later he found that the hot cathode could be made of platinum, instead of the carbon which Edison had always used. It was not until 1889 that J. J. Thomson showed that the effect was due to the emission of electrons.

Fleming also says "The second discovery I made was that negative electricity from any battery could pass from the hot filament to the cold metal plate, but not in the opposite direction. The space between the filament and the metal plate is a one-way street for electricity." He says that he described all these experiments in a lecture to the Royal Institution in 1890 and more fully to the Physical Society in 1896. Note those dates, 1890 and 1896. Many years before he took out his patent he described this rectification.

His first association with wireless telegraphy was in 1899, when he was appointed scientific adviser to the Marconi Company. He had much to do with the design and equipment of the station at Poldhu from which the first transatlantic signal was transmitted in December, 1901. It was in October, 1904, twenty years after his visit to Edison, that it suddenly occurred to him that the Edison effect could be used to rectify alternating currents of high frequency. The next day he ordered a dozen lamps with metal cylinders round the filament from the Edison Swan factory, and on November 16th he applied for a patent, which, according to the terms of his agreement with the Marconi Company, became their property. This was a bitter pill, for, in his own words, "as the original inventor of the thermionic valve I have never received a single penny of reward for it, other than the retainer paid to me for years by the Marconi Wireless Telegraph Company." He says "One firm has sold valves for years made exactly in accordance with my patent specification, which they advertised and sold as 'Marconi valves' although the Marchese Marconi had nothing whatever to do with the invention." This patent, which is the basic reason for our gathering here to-day, only referred to the diode rectifier.

* * *

About the same time as Fleming's visit to Edison and his introduction to the Edison effect, much research was being carried out by Elster and Geitel in Germany on a phenomenon which had been known for many years, namely, that when a metal is heated to incandescence the air in its neighbourhood becomes a conductor. They found that a metal plate in the neighbourhood of an incandescent filament acquired a negative charge, and that the effect was increased if the filament and plate are in an evacuated enclosure. In 1884 Hittorf in Germany noticed that if the cathode of a vacuum tube was heated to incandescence a small e.m.f. passed considerable current. So far as I know, however, no practical application of these findings was suggested. In 1904, the year in which Fleming took out his patent, Wehnelt noted that if a filament was coated with certain oxides the emission of electrons was greatly facilitated; hence equal emission could be obtained with a lower temperature with greater sensitiveness and convenience of operation.

* * *

The invention of the triode, the three-electrode valve, by Lee de Forest in 1906 was something for which Fleming never forgave him. It led to very much bitterness and almost endless litigation. Fleming had tried replacing the metal plate in the diode by a zigzag platinum wire to see whether or not it was as effective as the plate in catching the electrons. It is amusing to read in his autobiography that "Sad to say, it did not occur to me to place the metal plate and the zigzag wire in the same bulb and use an electron charge, positive or negative, on the wire to control the electron current to the plate." He says, "Lee de Forest, who had been following my work very closely, appreciated the advantage to be so gained and made a valve in which a metal plate was fixed near a carbon filament in an exhausted bulb and placed a zigzag wire, called a grid, between the plate and the filament. He thus put into one bulb the metal electrodes I had put into two separate bulbs and so made the first rudimentary form of the so-called three-electrode valve."

This I consider rather unfair. Fleming had taken a well-known device, the Edison effect, and simply applied it in a new way, namely, as a rectifier of high-frequency currents, whereas de Forest had introduced modifications of various kinds but all directed to the variation of the direct current passing through the valve from a battery by means of a third electrode either outside or inside the valve. In the subsequent patent actions the American courts held that de Forest's addition of the grid, though a contribution of value, was not independent of Fleming's invention, even if, as de Forest maintained, he was unaware of it at the time.

In his *Elementary Manual of Radio-Telegraphy* in 1908, to which I have already referred, Fleming says: "A very simple but effective form of oscillator valve was invented by the author in 1904, based upon researches made many years previously, namely, in 1890, upon the Edison effect in incandescent electric lamps." He then, without any mention of the third electrode, says: "This glow-lamp detector has been much used by Lee de Forest, disguised under the name of an Audion, and claimed as his own invention. It was, however, described in scientific papers and in patent specifications by the author long previously." This almost incredible distortion of the facts indicates the extreme bitterness of Fleming's feelings towards de Forest; and, as you will see, they were somewhat reciprocated.

The Fleming valve was purely and simply a rectifier or detector; it was in no way an intensifying device. While Fleming must be credited with being the first to apply thermionic phenomena to wireless detection, the intensifying properties of the present-day valve are far more important than its rectifying properties.

When the Fleming patent expired in 1918 the Marconi Company applied for an extension, mainly on the ground that on account of the 1914–18 war they had not been able to develop and make full use of the patent. The application was opposed by a number of firms and Government departments. The case was fought out in the Law Courts, in December, 1918, and the petition was dismissed.

* * *

An interesting question is the extent to which Fleming's invention was adopted in the wireless industry. In looking up a paper which I read at the British Association meet-

ing at Portsmouth in 1911, on "Recent Developments in Radiotelegraphy," I find that I said: "The filings coherer has practically disappeared. The magnetic detector used by the Marconi Company is ideal in its simplicity and reliability, but is not so sensitive as the electrolytic or mineral contact detector. The Telephone Company has recently given up the electrolytic detector in favour of a detector of the latter type. Another type of detector used to a certain extent is the Fleming valve, which combines extreme sensitiveness with comparative simplicity and reliability." That was in 1911, seven years after the patent.

[Professor Howe then read a quotation to show the relatively small effect that the two-electrode valve had on wireless ten years later, in 1921.]

The Thermionic Valve in America

Now let us consider the genesis of the thermionic valve in America.

The Edison effect was well known and twenty years old. Fleming did not modify it in any striking way, but simply used it as a rectifier. His invention alone made no outstanding contribution to the reception of wireless signals. It did not replace the crystal detector or the magnetic detector to any great extent, and I can well believe that it was not known to de Forest or his associates, who were experimenting with various devices along lines entirely different from those of the Fleming valve. Lee de Forest had been working on this problem since 1902 and had taken out about forty patents before the end of 1906. Some of these were for gas flame detectors in which the electrodes were two platinum wires with a gap between them in the flame of a bunsen burner. He always used a circuit containing a battery and telephone receiver and gas gap in series, and connected the aerial to one side of the gap and the receiver to the other, so that the received signal affected the gap and caused a change of current through the telephone receiver. It was on the advice of his assistant Babcock that he got a local electric lamp maker to make him a lamp with a platinum plate inside, but he still used it with a local battery and not as a rectifier. After experimenting with the aerial connected to a strip of tinfoil wrapped round the outside of a glass tube, he got the lamp maker to put two metal plates inside the bulb, one on each side of the filament.

It then occurred to him that the control electrode would be more efficient if placed between the plate and the filament and, after trying a perforated plate, he decided to replace it by a wire grid. From the beginning there is no suggestion of rectification of the high-frequency current; its function is always to control the output of his battery. It is interesting to note that de Forest's patent application of October 25, 1906, relates to devices for amplifying feeble electric currents, not detection of them. It was some months later, on February 18th of the following year, that it was stated that the patent relates to "wireless telegraphy receivers or oscillation detectors." The first patent was not for detection, but for amplifying, and the second was for detection. It has been stated that de Forest invented the metal filament, but that is not correct, for in 1890 Fleming had found that the hot cathode could be made of platinum and not of carbon, as used by Edison.

The subsequent history of de Forest's patents is very unfortunate. After three or four years, owing probably to financial difficulties, de Forest allowed the British patent to lapse, with the result that the Marconi Company could make and sell in this country three-electrode valves if they wished to—an additional reason for their wanting an extension of the Fleming patent. In the U.S.A., after much litigation, the courts decided that de Forest could not make three-electrode valves without infringing the Fleming patent, and that the Marconi Company could not make them without infringing the de Forest patent, with the result that the industry was in a tangled mess until the Fleming patent expired in the United States in 1922.

This was, however, not the end of the story, for in 1943—jumping twenty years—two years before Fleming's death, the U.S. Supreme Court decided—because the case was still going on in America!—that the Fleming patent was entirely invalid, and had always been so from the beginning, on the ground that Claim 1 was not limited to high-frequencies, but included all frequencies, whereas Fleming's earlier publications had shown that the rectifying properties of the valve were known. In 1915 the Marconi Company had made a disclaimer limiting its patent to high-frequencies. When the application was made for an extension of the Fleming patent it was not the original patent which was to be extended, but only a certain portion of it; they disclaimed some of it. In the United States, however, the Supreme Court held that Fleming's claim for more than he had invented was not inadvertent and that his delay in making the disclaimer was unreasonable. This improper claim, for something not the invention of the patentee, rendered the whole patent invalid. It could only have been saved by a timely disclaimer, which was not made.

In conclusion, I should like to quote from something which de Forest wrote when he published his autobiography in 1950, which, with characteristic modesty, he entitled "The Father of Radio." He concludes his reference to Fleming by saying: "He was unregenerate at the age of ninety-two, and, having married a young opera singer when he was eighty-four, he lived to the ripe old age of ninety-five, dying in 1945, and he never yielded in his firm conviction that he was radio's true inventor."

Engine Testing Plant

An engine test house forming a self-contained building has recently been designed and put into operation by David Brown Tractors (Engineering), Ltd., at its Farsley Works, near Leeds. Experimental work carried out during recent years at the company's main headquarters at Meltham, near Huddersfield, has largely influenced the design and methods chosen for the new test plant. It will be used for running in and power testing the engines which are assembled at Farsley for fitting in the company's cars and tractors.

Five fuels are laid on direct to the test beds. Coal gas is selected for running-in purposes, and gas oil, vaporising oil, petrol and lamp oil are fed from storage tanks alongside the main building. The new test plant has seventeen dynamometer test beds and nine running-in beds for tractor engines, three test and three running-in beds for car engines, with provision for almost double that capacity. Centrally placed on the west side of the test house is an enclosed section devoted to storage, inspection and testing of diesel injector equipment.

Since water is used as the hydraulic medium in the dynamometers, as well as for cooling purposes, the plant has been equipped with a pumping house and cooling system to effect recirculation. Water is supplied to the dynamometers and to header tanks on each test bed by a pump capable of delivering 15,250 gallons per hour. A second pump passes the hot water to a cooler. Another pump circulates water through an oil system on the car engine beds.

Some of the dynamometer test beds, showing in the foreground high-speed petrol engine on test in one of the sound-insulated cubicles

Noise outside the building has been kept to a minimum by piping each exhaust to an absorption silencer mounted on the outside wall. Single-chamber silencers are fitted on the exhausts from the tractor beds, but the silencers on the much faster running car engines have primary and secondary chambers.

The decision to run-in engines on coal gas was made on the grounds of both economy and efficiency, for gas is not only a cheap fuel, but has the added advantage of leaving little solid deposit in combustion. The method when running-in is to provide initial impulse through an electric motor using a clutch which automatically disengages at 750 r.p.m.

The high-speed car engines run in three sound-insulated cubicles in a separate section of the building, and are coupled to dynamometers positioned outside the cubicles. On account of the high engine speeds these dynamometers have stainless steel elements, and electric tachometers, reading up to 8000 r.p.m.

Coal Preparation Plant at Mansfield Colliery

A coal preparation plant installed at Mansfield colliery is designed to handle some 400 tons of coal an hour. In it the "Chance" sand flotation process is combined with a froth flotation equipment for handling the material below $\frac{1}{16}$in square, and this is believed to be the first installation of a combined heavy medium-froth flotation process.

As part of the extensive reorganisation and reconstruction programme at Mansfield colliery, in the East Midlands Division of the National Coal Board, a new coal preparation plant manufactured by the Fraser and Chalmers Engineering Works of The General Electric Company, Ltd., has been installed to replace two existing plants which had completed their useful life. Particulars of this plant which is designed to deal with the whole output of the mine—about 400 tons an hour—have been received from the Fraser and Chalmers Engineering Works.

In the new plant the coal is cleaned by two processes—a "Chance" sand flotation process for sizes above $\frac{1}{16}$in square and a froth flotation equipment for the sizes below. It is believed that this plant is the first of its kind to be installed where the whole of a pit output is cleaned in a combination of a heavy and medium-froth flotation processes.

The construction of the plant at Mansfield presented many difficulties as existing washeries and a hand cleaning section had to be kept in commission whilst the new plant was being installed. The new clean coal screening and loading section had, in fact, to be built on top of the old equipment and the various picking belts replaced by boom loaders, one by one, during the week-ends. During this changeover the hinged jibs of the boom loaders were propped up and used temporarily as picking belts, until the new plant was commissioned.

Numerous examinations of the raw coal were carried out before the contract for the plant was placed and, from a study of the results, it became apparent that the various products required could best be obtained by installing two Chance cones for dealing with the coals above $\frac{1}{4}$in in size. The reason for this decision was that the coal sizes above $\frac{1}{2}$in diameter contained a certain proportion of intergrown middlings, which could be improved upon crushing, whereas it was not considered worth while to produce middlings in the $\frac{1}{2}$in diameter by $\frac{1}{16}$in square fraction, whilst in any case a higher ash content was permissible than with the plus $\frac{1}{4}$in fraction. Consequently, one 14ft diameter Chance cone was installed, with middlings extraction equipment, for dealing with the plus $\frac{1}{4}$in size; and a second cone, of the same diameter, was installed for dealing with the $\frac{1}{4}$in diameter by $\frac{1}{16}$in size. The mechanical parts, &c., for both cones are similar and interchangeable.

One of the diagrams reproduced on this page shows the coal flow of the new preparation plant. The raw coal is normally brought up the No. 2 shaft of the mine in 7-ton skips and discharged on to a plate feeder belt *A* via a 10-ton receiving bunker, which also acts as an air seal. Three doors are fitted to the bunker, two at the top and one at the bottom, and they are controlled by compressed air, the valves being operated by the skips as they reach and leave the discharge position. The bottom door closes when the top door opens and vice versa, and a photo-electric device is fitted to warn the engineman if the door of the skip fails to close securely.

It was found convenient to screen out the 8in diameter coal from the run of mine feed to the plant and to crush the plus 8in to minus 8in. The plus 8in fraction contains a large percentage of intergrown material which is released on breaking. The coal is delivered to the primary screen from the plate feeder belt *A*, via belt conveyor *B* in order to make the separation at 8in. From this screen the 8in and below fraction passes directly to conveyor *F*, whilst the plus 8in size is fed on to picking belt *E*. The picking belt is used for the removal of any exceptionally large pieces of stone, together with tramp iron, pit props, &c., and it is fitted at its discharge end with a "Plowright" pick breaker to reduce the plus 8in coal to minus 8in. This broken coal then joins the coal on conveyor *F* for delivery to the main section of the coal preparation plant.

Facilities are also included on the picking belt, whereby a special hand-picked selected large coal can be delivered directly to wagons when required.

The conveyor *F* delivers the 8in and below raw coal on to the two secondary raw coal screens for wet screening at $\frac{1}{2}$in diameter, the 8in to $\frac{1}{2}$in fraction being delivered to the No. 1 "Chance" cone shown in the illustration on page 748 via conveyor *G*. The $\frac{1}{2}$in and below coal, together with all the spray water, is laundered to a battery of six "Sherwen" electro-magnetically vibrated screens where a separation, by means of wet screening, takes place at $\frac{1}{16}$in square. The separation takes place in the first 12in to 15in of the screens.

The $\frac{1}{16}$in and below fraction, separated on the "Sherwen" screens is laundered to a slurry basin, from which it is pumped to the flotation plant, whilst the $\frac{1}{2}$in to $\frac{1}{16}$in fraction is delivered to the No. 2 "Chance" cone via conveyors *H* and *J*.

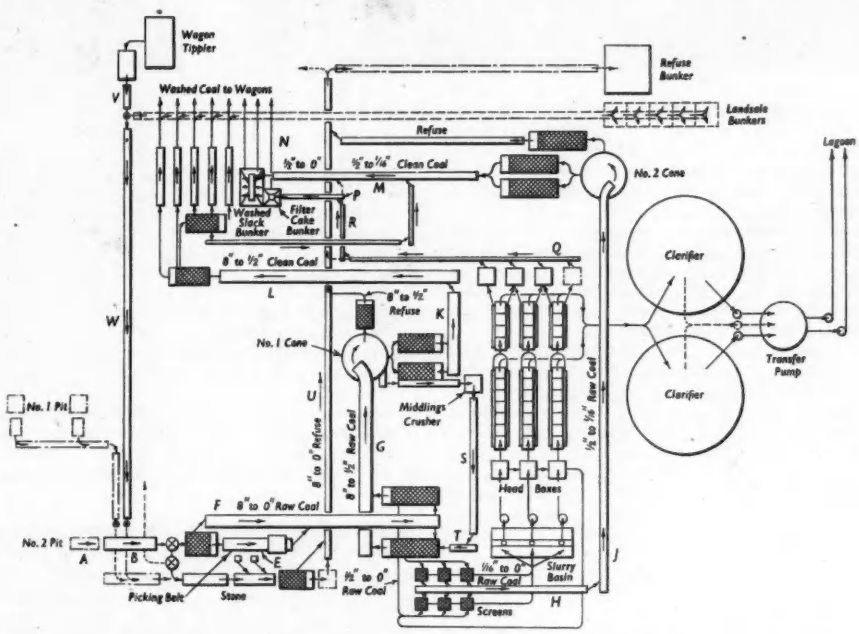
The No. 1 "Chance" cone is arranged for a three product separation, namely, clean coal, middlings and refuse. The refuse, after desanding and dewatering, is delivered by a conveyor *U* and on to an aerial ropeway to a 200-ton refuse bunker.

The clean coal, from the No. 1 "Chance" cone, is laundered on to a pair of clean coal desanding and dewatering screens, and delivered via conveyors *K* and *L* to the sizing screens. The latter separate the clean coal into 8in by 4in, 4in by 2in, 2in by 1in and 1in by $\frac{1}{2}$in, for loading to wagons, via boom loaders. A spare boom loader has been provided so that the number and range of the sizes may be altered to accommodate changes in the market requirements.

The 8in to $\frac{1}{2}$in middlings fraction extracted from the No. 1 cone, by means of the middlings column, is desanded and dewatered on a section partitioned off on one of the clean coal desanding and dewatering screens. This material is then crushed to minus $\frac{1}{2}$in in a hammer mill, and returned to the secondary raw coal screens via conveyors *S* and *T* for separation into $\frac{1}{2}$in to $\frac{1}{16}$in and $\frac{1}{16}$in and below along with the raw coal feed, for delivery to the No. 2 "Chance" cone, and to the flotation plant, respectively.

The No. 2 cone is arranged for a two product separation only and the refuse, after desanding and dewatering, is delivered to the refuse bunker by conveyors. The clean coal is desanded and dewatered on a further pair of shaker screens and delivered to a 300-ton loading bunker, via conveyors *M* and *N*.

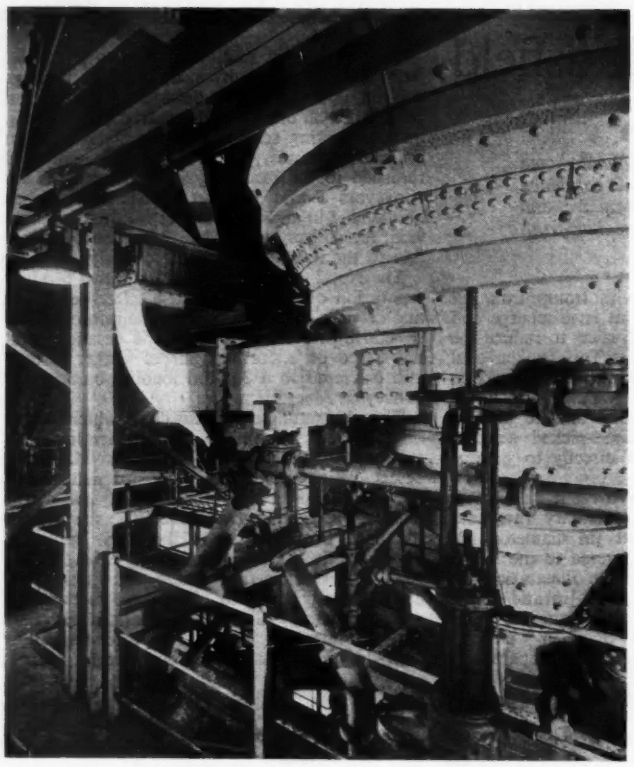
The $\frac{1}{16}$in and below raw coal, which passes into the slurry basin as already mentioned, is pumped to the flotation plant via the head boxes, which remove any oversize material in the feed, and control the quantity of slurry delivered to the flotation cells. The slurry from the head boxes passes to the three banks of primary cells, each bank consisting of seven cells. The concentrates from these cells may pass either directly to three 200 square feet unifloc rotary vacuum filters, or alternatively, they may be retreated in a set of three banks of secondary cells, each bank consisting, in this case, of four cells. At present it has been found possible to clean the $\frac{1}{16}$in and below material satisfactorily in the primary cells, without using the secondary cells. The tailings product from the cells is laundered to two 75ft diameter clarifiers.



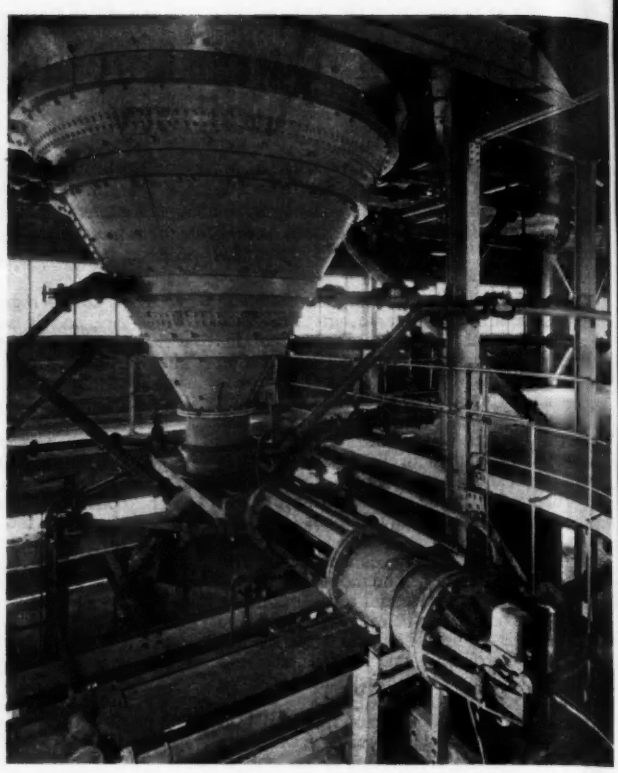
Coal flow diagram of preparation plant in which "Chance" sand flotation and froth flotation processes are combined

Water from the clarifiers overflows into a sump for reuse in the washery, whilst the thickened sludge is extracted from the bottom by two diaphragm pumps. These pumps discharge into a transfer sump, from which two centrifugal sand pumps deliver the material to a lagoon 800 yards away. Due to the coarse size of the tailings, the solid material settles out very

After dewatering on the rotary vacuum filters, the cake is discharged on to conveyor *Q* and delivered to conveyor *R*. This conveyor *R* is arranged with an adjustable chute so that the filter cake can be mixed with the washed slack, on conveyor *M*, or alternatively, loaded to wagons separately, via conveyor *P* and a filter cake bunker. Provision has been made to permit installation of a further vacuum filter in the future, if the amount of fines increases.



No. 1 " Chance " cone for handling 8in to ½in coal, and the middlings extraction column



No. 2 " Chance " cone and refuse extraction equipment

quickly in the lagoon and it is possible to pump the water back to the washery and maintain a closed circuit.

The two-process combination of washing results in a very simple water circuit. Water is added on the secondary raw coal screens, for extracting the minus ½in and this coal, together with the spray water, passes to the " Sherwen " screens for a further separation.

A small quantity of water is continuously bled from the " Chance " cone circuit, to keep the solid concentration to a satisfactory level, and this effluent is used to assist the wet screening. The balance of the spray water is provided by the clarified water pump. After it has been separated on the " Sherwen " screens, the $\frac{1}{16}$in and below coal passes to the slurry basin, which serves to even out the washing characteristics and solid concentration of the feed to the flotation cells.

The arrangement of the water circuit ensures that the fine material is extracted from the feed immediately it enters the plant, thereby avoiding a considerable measure of degradation, as recirculation is avoided.

All conveyors handling wet or sticky materials are provided with special collecting troughs for spillage under the return side of the belt. These troughs are continuously flushed with water which is drained either to the slurry basin or effluent pit, the solids being recovered in the flotation plant.

In addition to the equipment for cleaning the raw coal, the plant includes facilities for dealing with run of mine pit stone. The stone may be brought up either of the two shafts and, after passing over a steel plate picking belt, for the removal of any free coal, it is screened at 8in, the plus 8in material being reduced to minus 8in in a jaw crusher. The whole of the 8in pit stone is then discharged on to the rubbish conveyor and thence to the 200-ton refuse bunker. Winding of the stone usually takes place off shift, but it is possible to handle it during the period of coal winding.

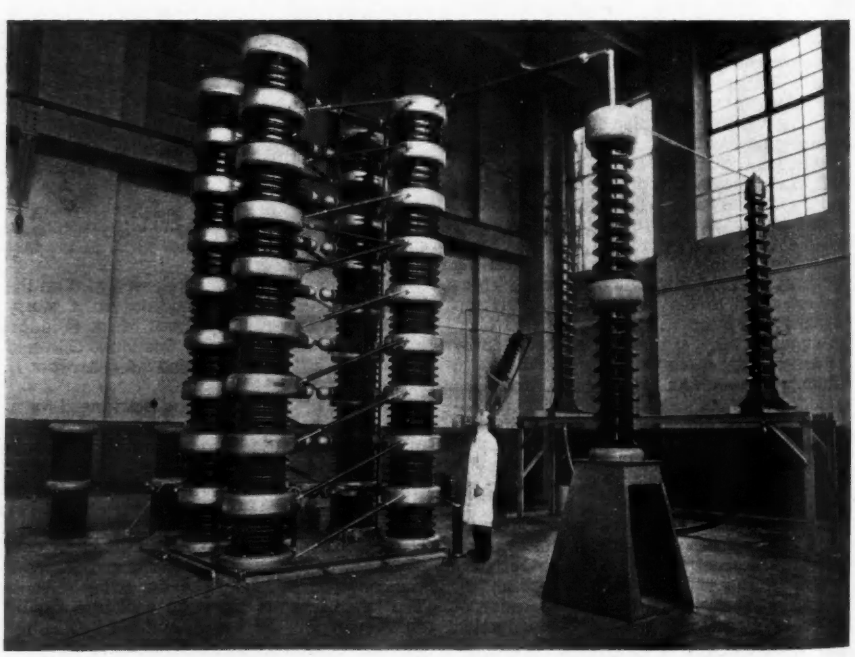
Provision has been made whereby in the future the hinged jibs of the loading booms may be lifted up and discharged on to a conveyor, so that any of the washed coal sizes may be loaded into bunkers for land sale.

The rubbish disposal facilities include arrangements at the discharge end of conveyor whereby rubbish may be loaded into rail wagons, in the event of the ropeway being out of commission. If the plant is out of commission, raw coal or pit stone may be loaded to rail wagons and, thereafter, reintroduced into the preparation plant by means of a wagon tippler and conveyors *V* and *W*.

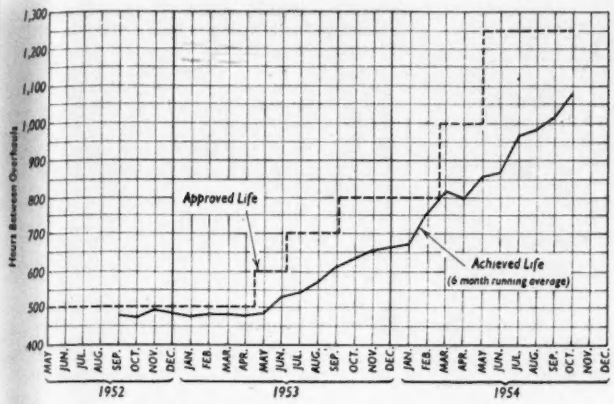
In addition to supplying the mechanical section of the plant, the Fraser and Chalmers Engineering Works acted as main contractor for the whole of the civil engineering work and was also responsible in collaboration with the Witton Works of the G.E.C., for the whole of the electrical installation. The belt conveyors and screening and loading sections were supplied by Plowright Bros., Ltd., of Chesterfield, whilst the civil engineering work was sub-contracted to Holst and Co., Ltd., of Berkhamsted, and the heating plant to Seymour Sweet and Co., Ltd., of Birmingham. Unifloc, Ltd., was responsible for the supply of the froth flotation plant, together with the rotary vacuum filters and water clarification plant.

1½ Million Volt Impulse Generator

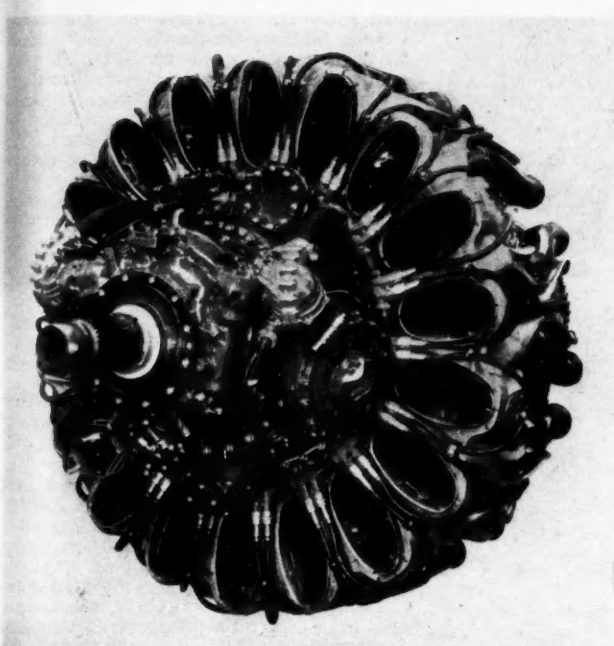
We illustrate a nine-stage impulse generator with a maximum crest voltage of 1575kV, which has been installed in the North Woolwich works of Standard Telephones and Cables, Ltd., where it will be used for investigating the impulse



Nine-stage impulse generator having maximum crest voltage of 1575kV and energy output of 22kW-seconds



Life of " Centaurus 661 " between overhauls



Bristol " Centaurus 661," eighteen cylinder, two row radial engine

characteristics of high-voltage cable and accessories, capacitors and insulating materials.

This impulse generator employs a Marx circuit whereby a group of condensers are charged in parallel and discharged in series. The energy output is given as 22kW-seconds, the wave shape being 1150 microseconds. Charging of the condensers, at either polarity up to 175kV, is effected through metal rectifiers supplied from step-up transformers under the control of a moving coil regulator. Surge voltage measurements are made with a capacitance potential divider, the results being observed or recorded photographically with a sealed-off cathode-ray oscillograph. One metre sphere gaps are also installed, to serve as a reference standard for voltage measurements.

Engine and Propeller Overhaul Life

THE Air Registration Board has authorised a further extension of the inter-overhaul period for Bristol " Centaurus 661 " engines in " Elizabethan " airliners of British European Airways, increasing the overhaul life from 1000 to 1250 hours. The " Centaurus 661 " has been in airline service only about two and a half years and the authorised overhaul life of 1250 hours was reached after only 100,000 engine hours, an achievement believed to be without parallel. Over 80 per cent of B.E.A.'s engines now run to their full approved overhaul lives before they are removed from the aircraft. At the same time the average achieved overhaul life now exceeds 90 per cent of the authorised figure. The performance of the first two " Centaurus 661 " engines to complete 1250 hours' running was afterwards checked on the dynamometer, and it was found that both engines were still within the acceptance limits for new units. Take-off power was down by less than 1 per cent while engine oil circulation rates were unchanged, a reasonable indication that the wear on engine components had been negligible.

Frequency of Engine Failure

Year	Engine hours per failure
1952	9100
1953	8340
First half of 1954	7530

The overhaul life of the " Centaurus " now corresponds with the major airframe overhaul period. This represents a major economy to the airline, as it means that engine changes need now normally be made only when the aircraft goes in for its check 4 overhaul. Another index of the reliability of the engine is the number of engine hours achieved per failure, and this for the " Centaurus 661 " in the " Elizabethans " is shown in the table.

These figures are comparable with the best achievements of the " Hercules " radial engine, which has been in service much longer, and are among the best achieved with an aeronautical engine. The growth of the overhaul life is shown in the figure. The " Centaurus 661 " engine illustrated is a two-row, eighteen-cylinder, sleeve-valve engine of 53·6 litre capacity. It has a specific weight of 1·26 lb per horsepower, and a specific fuel consumption of 0·42 lb per horsepower per hour. It has a maximum rating of 2705 h.p. at 2800 r.p.m. (4000ft).

The Air Registration Board has also approved a 40 per cent increase in the overhaul life of the de Havilland propellers fitted to the " Hercules " engines on Bristol " Freighter 31 " and " 32 " aircraft. The overhaul life, currently 1000 hours, is increased to 1400 hours, an advance made possible by a long period of satisfactory service.

OPENING OF SHOWROOMS.—To mark the opening of its lamp and lighting showroom at Crown House, Aldwych, London, W.C.2, the British Thomson-Houston Company, Ltd., is showing an exhibition, " Lighting Through the Ages." It is seventy-five years since Thomson and Houston established their partnership. In 1878, Joseph Swan had demonstrated an incandescent lamp, and in 1879 Thomas A. Edison, working independently, produced the carbon filament lamp. An extensive collection of electric lamps is on view, from the early socketless designs to modern 1kW mercury vapour discharge lamps, and 10kW incandescent lamps. Other exhibits include a germicidal lamp, the " Mazda FA.5," xenon flash tube, and a range of projection lamps and photographic flash bulbs. Various demonstration units illustrate the effect of light composition on colour. The earliest exhibit from the pre-electricity era is a Phœnician oil lamp, and the dangers and discomforts attending the use of oil and gas lighting in the last century are vividly illustrated by comtemporary humorous prints and notices regarding safety in theatres. The wiring of the exhibition is laid in " Invertrunking " channels, a system which the company has developed and which makes it easy to alter the layout as may be required on future occasions.

African Engineering News

BY OUR SOUTH AFRICAN CORRESPONDENT

Chemical Engineering Firm's New Factory

In view of the expected development in Natal of new industries requiring supplies of chlorine and caustic soda, African Explosives and Chemical Industries, Ltd., has cleared 20 acres of bush on the site of its Umbogintwini factory to make way for roads, railways and seven groups of buildings which will comprise their new plant. The new plant will have a floor space of 137,000 square feet and will be laid out on a generous scale to allow for rapid expansion. The cost of construction will be about £2,000,000 and a considerable portion of the plant, including pressure vessels, is being manufactured in South Africa. It may be necessary to import a high-grade salt, but it is hoped eventually to use a local product.

Most of the caustic soda will be sold at 45 per cent liquor, but some will be processed with chlorine to form a solution of sodium hypochlorite. This section of the plant is designed to produce several thousand tons of hypochlorine liquor per annum. Some thousands of tons of polyvinyl chloride will also be manufactured annually from local raw materials. It is expected that all sections of the plant will be in operation by the middle of next year.

Phosphate Production

The dismantling of the Vereeniging plant of the African Metals Corporation, Ltd., since that plant was closed down at the end of March this year, and its re-erection at the new Kookfontein site, is proceeding satisfactorily. An electric furnace plant and equipment for the initial production of 10,000 to 12,000 tons of dicalcium phosphate per annum will be installed at the new plant, the plant being designed to allow for increased output if desired. It is expected that the plant will come into operation at the end of next year. Meanwhile, arrangements have been made to continue, as far as is possible, production on a small scale in the pilot plant, which is being transferred from the old to the new works.

Rayon Pulp Industry

Natal's £8,000,000 rayon pulp industry is expected to go into production next year and to increase South Africa's export trade by £3,000,000 per annum. Its total production of 40,000 tons of rayon pulp a year will be sold in equal parts to Italy and Britain. The plant now being installed at Umkomaas will eventually be one of the biggest projects of its type in the world, it is stated, and its initial rate of production will entail a daily consumption of 400 tons of saligna gums. To ensure that this supply will be forthcoming the South African Industrial Cellulose Corporation has already bought thousands of acres of gum plantations in Zululand.

The site has its own steam-driven power station, and a large water purification plant. The factory borders on the Native Reserve, and will be one of the Union's first industries in the " closer settlement " schemes, whereby industry goes to the source of labour, and not the other way round. Two hundred and fifty Italian artisans and technicians are now living in and around Umkomaas. At first all the rayon pulp produced at the factory will be exported, but eventually it is hoped that the actual processing of rayon yarn will be done at Umkomaas.

The transformation of the saligna gums into rayon pulp is a fairly lengthy and complicated process. First, the logs are run through powerful chipping machines which break them down into small chips about ¾in long. The chips are then " cooked " for four to six hours in water and chemicals in the " digesters "—five vessels, each 50ft high and 18ft in diameter. The product is then washed, screen treated with various chemicals and run through the " bleachers." The pulp, which looks like wet cotton wool, is then put through a sheeting machine—a sequence of rollers—from which it emerges looking like thick blotting paper. From here it goes into the driers to have excess moisture removed, and is finally cut into lengths and baled.

Two Small Marine Diesel Engines

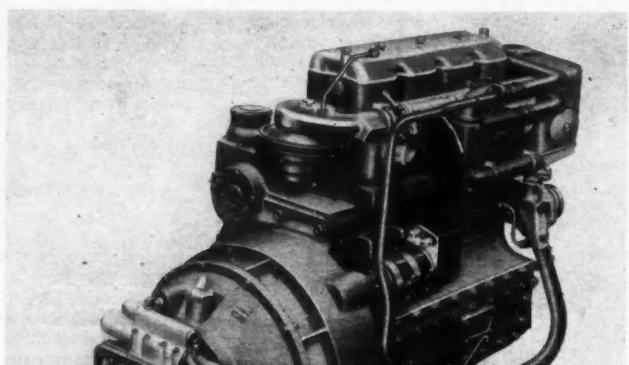
LAST month, in the marine section of the Motor Show, W. H. Dorman and Co., Ltd., exhibited two new marine engines, the smaller being a four-cylinder unit, Mark 4LA/M, and the larger engine being a six-cylinder model and designated 6KA/M. Both engines meet the requirements of the Ministry of Transport and are built to Lloyd's classification.

The Mark 4LA/M engine, shown in the upper photograph, has a bore of 120mm and stroke of 130mm and a capacity of 5881 c.c., the b.h.p. at the corresponding crankshaft speed being as follows :—

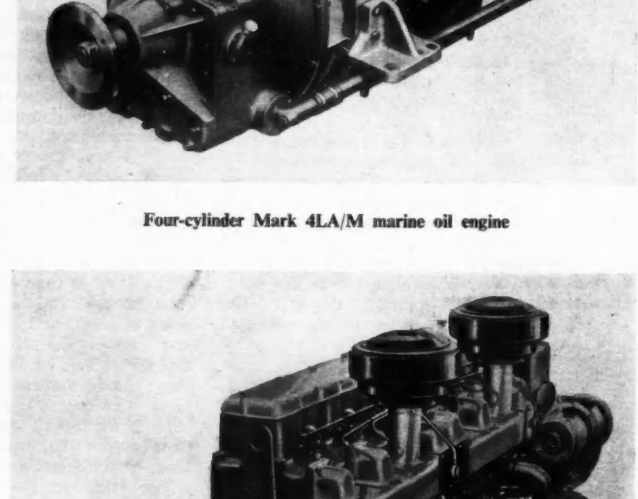
B.h.p. output at shaft ...	29·5	39·0	48·0	55·0	60·7	64·5
Crankshaft r.p.m. ...	800	1000	1200	1400	1600	1800

The crankcase and cylinder unit is of rigid cast iron monobloc form, extending below the crankshaft centre line, in the lower portion of which are housed the crankshaft and camshaft bearings, while the upper part contains chrome-hardened wet cylinder liners. For the removal of the big ends and for inspection purposes there is a large cover plate on the starboard side of the engine. The cylinder head is a single unit with integral rocker brackets and including a high wall valve chamber housing the overhead valve gear and fuel injectors. Renewable valve guides and seats are fitted. The camshaft is carried in the crankcase and the cams, which are lubricated by dipping into an integrally cast oil bath, operate chilled face bucket pattern tappets, which reciprocate in guides integral with the cylinder cover plate. There is one exhaust and one inlet valve per cylinder, each actuated by hardened overhead rocker arms and push-rods, and the motion is controlled by dual valve springs. A hand-operated valve decompressor is provided.

Low expansion aluminium alloy is used for the pistons, which have three compression rings and two slotted oil control rings; one oil control ring is below the push fit gudgeon pin, which is of alloy case hardening steel and secured by circlips, the remaining rings being above. Alloy steel H-section stampings form the connecting-rods, having a silicon-bronze bush at the small end and a strip pattern, steel-backed, copper-lead lined, big end bearing, prefinished in the bore, and split at an angle to allow the rod to pass through the cylinder bore. Five prefinished strip pattern, steel-backed, copper-lead-lined bearings carry the "High-Duty Meehanite" crankshaft, which has a journal diameter of 3¾in. There is a diaphragm fuel-lift pump complete with a hand priming device, and the fuel is delivered to the engine by a C.A.V. multi-cylinder precalibrated base-mounted "N" pattern injection pump through multi-hole nozzles. Dual parallel-flow paper element filters are fitted, also an excess fuel button to assist starting from cold. The lubricating oil, which is carried in a detachable sump of 4¼ Imperial gallons capacity and fitted with a gauze suction strainer, is delivered by a gear pattern pump to a relief valve, then to an oil stabiliser and through full-flow filters to the principal bearings. Cooling is by means of fresh water, the system including a keel cooling unit, which is circulated by a centrifugal pump, belt driven from the cam shaft. The other auxiliaries such as the fuel injection pump, oil pump, dynamo and the cam-shaft, are driven by helical gearing at the aft end of the engine. Starting is by means of a cradle-mounted axial starter, and there is a flange-mounted dynamo driven from the main gear train, while the engine is controlled by a pneumatic governor forming part of the fuel pump assembly. The final drive is through an oil-operated reverse gear and the engine, which has a four-point attachment, has a maximum installation angle of 10 deg.



Four-cylinder Mark 4LA/M marine oil engine



Six-cylinder Mark 6KA/M marine oil engine

The six-cylinder engine, which we illustrate, has a bore of 135mm, a stroke of 160mm, a capacity of 13,741 c.c., the power developed being :—

B.h.p. output at shaft ...	74·0	95·0	116·0	133·0	138·7	
Crankshaft r.p.m.	800	1000	1200	1400	1500	

The cast iron crankcase has a number of inspection doors and there is a detachable monobloc cylinder casting housing six chrome-hardened wet liners, while the cylinder heads consist of two interchangeable units, each housing the overhead valve mechanism and injectors for three cylinders. Renewable valve guides and seats are fitted and the camshaft, which is chain driven, is carried in seven renewable plain bearings Each cylinder has one exhaust and one inlet valve and they are operated by hardened rockers and pushrods, which are actuated by hardened flat tappets and hardened cams. The gear includes a hand-operated valve decompressor. Pistons and connecting-rods similar to those in the four-cylinder engine are fitted, except that both the connecting-rod bearings are steel backed, copper-lead lined and prefinished in the bore. The crankshaft, of "High-Duty Meehanite," has a 4in diameter journal, is supported in seven prefinished steel-backed copper-lead bearings, has an outboard bearing at the forward end to support a power take-off shaft, and a torsional vibration damper. As in the smaller engine, the fuel injection equipment is of multi-cylinder design and includes a plunger pattern lift pump incorporating a hand priming device, a prefilter with sediment bowl and a twin changeover fuel filter.

Twelve gallons of lubricating oil are carried in the sump casting, which has detachable side covers, one of which supports a suction strainer. The oil is delivered to the stabiliser before passing to the relief valve, preset to maintain a constant pressure of 40/45 lb per square inch at full speed, and then on through a full-flow twin change-over filter to a main gallery pipe. A chain-driven pump circulates fresh water through the engine and keel cooling unit. A 6in diameter cradle-mounted axial starter is provided and there is a 5in diameter cradle-mounted dynamo driven by a rubber belt having adjustable tensioning. A centrifugal variable-speed governor forming part of the fuel pump assembly is provided, and the engine, which has a four-point attachment and a maximum installation angle of 10 deg., drives through an oil-operated reverse gear.

Technical Report

B.I.O.S. Surveys Report No. 34, *The German Plastics Industry during the period* 1939–1945. By N. J. L. Megson, D.Sc., and H. J. E. Poupart, B.Sc. London : H.M.S.O., price 6s., post 6s. 3d. (1 dollar 40 cents U.S.A.).—This publication completes the series of surveys dealing with Germany during the period 1939–1945, prepared by the British Intelligence Objectives Sub-committee. The report is based on information collected in the C.I.O.S., B.I.O.S. and F.I.A.T. reports and various other documents. It deals with polymeric products used for plastics, ancillary substances, fabrication techniques and main applications ; only in special cases does it deal with elastomers, paints or textiles, which are treated in other reports of this series (Nos. 7, 22, 13 and 33, respectively). The exceptions are Polyuretanes and plasticised P.V.C., and special resins for paints, on the one hand, and the production of polymers for spinning, on the other. Lists of references at the head of each section supplement the bibliography of sources, and five appendices deal with special applications and certain trade names not mentioned in the text. The documents referred to are available at the Technical Information and Documents unit of D.S.I.R., Cunard House, 15, Regent Street, London, W.1.

Boundary Layer Control

By Dr. Ing. G. V. LACHMANN, F.R.Ae.S.*

No. II—(*Concluded from page 714, November 19th*)

In this very significant paper, which was read before the Royal Aeronautical Society on Thursday, November 11th, the author discusses the principles and the methods of application to aircraft of boundary layer control, both for the purpose of increasing the lift and for obtaining laminar flow. In the first part the author discusses methods of preventing by boundary layer or circulation control the separation of flow from the surface of an aerofoil and their application to existing aircraft using modified flaps. The second part is concerned with the attainment of laminarisation through distributed suction of the boundary layer. In both forms the author provides a brief historical review of the theory, research and application undertaken in different countries. The paper is confined to non-classified reports. The author maintains that the practicableness of this integration of engine power and lift has now been fully established and that much leeway in flight development has to be made up in this country. With the modest achievement of only 50 per cent laminarisation, the thrust requirements are halved, range is increased by 45 per cent, and optimum cruising height reduced by 14 per cent.

Methods of Propulsion for Laminarised Aircraft

Drag and propulsion of laminarised aircraft are much more closley interrelated with each other than on conventional aircraft, and the power plant must be tailored to suit the special requirements in order to reap the full benefit from boundary layer control.

It is not enough to remove part of the boundary layer to control its growth and improve its stability so that it will stay laminar over the whole chord of the wing. It is also necessary to re-energise the sucked air to free stream velocity.

Their necessity was soon appreciated by the pioneers of boundary layer control. Pfenninger deduced from his early experiments in Zurich with an aerofoil of 17 per cent thickness that if the sucked boundary layer were not accelerated to free stream velocity, i.e., with absolute velocity of suction air equalling flight velocity, the effective profile drag coefficient (wake drag plus pump drag) was 0·0038. However, if the sucked air was accelerated to stream velocity, and assuming equal efficiency for suction blower and propeller, the effective drag coefficient was only 0·0023.

In other words, what we call laminarisation through boundary layer suction is not only a method of stabilising a laminar boundary layer, but it comprises implicitly a form of re-energising the boundary layer.

The step from there to boundary layer propulsion is a short and obvious one.

Since the wake drag of a laminarised wing is very small, it can be equalised by the momentum of the mass of the sucked air expelled at a velocity somewhat in excess of flight velocity.

Denoting with :—

D_i = induced drag.
D_B = body drag plus other form drag.
D_W = wake drag of wings and tail surfaces (no suction).
ΔD_W = wake drag of wings and tail surfaces (laminarised aircraft).
T = thrust by conventional methods (propeller, straight jet, ducted fan).
D_P = equivalent pump drag, i.e. pump work expressed in form of a drag.

the conventional form of propulsion is expressed by

$$T = D_i + D_B + D_W.$$

Applying this method to an aircraft with laminarised wings and tail surfaces

$$T^1 = D_i + D_B + \Delta D_W + D_p.$$

An advantage of Scheme II over Scheme I results if

$$\Delta D_W + D_p < D_W.$$

ΔD_W is very small in case of full chord laminar flow and can be neglected in first approximation. The power plant of a laminarised aircraft must, therefore, supply sufficient power to drive the suction blowers which accelerate the boundary layer to, or beyond, free stream velocity. In addition sufficient thrust must be made available to overcome the induced drag, body drag and any remaining wake drag when the suction blowers are not incorporated in the thrust system.

While propeller-turbines with power off-take for driving the blower would seem to be a very economical solution (also possessing a very favourable take-off thrust/cruising thrust ratio), it is difficult to use them for driving pusher airscrews, unless they are paired with their axes normal to flight direction and driving coaxial propellers by means of bevels and shafts. With a single turbine driving a pusher propeller it is difficult to get rid of the exhaust gases in the jet which would have to pass through, or over, the hub.† Furthermore, the effect on the boundary layer of the inflow into the propeller disc area is not known. There is also the danger of vibrations set up due to the flaps.

An ideal position for pusher airscrews on a laminarised aircraft would be at the tail end. Such an arrangement was once demonstrated by the Douglas Company in the U.S.A., a long shaft drive and gears being used. However, such an arrangement—apart from the mechanical complication—would lead to uncomfortably high disc loadings for multi-engined aircraft.

In view of these difficulties associated with turbine-driven propellers and also, taking account of their decreasing efficiency at Mach numbers approaching $M = 0{\cdot}8$, the advantage seems to be with ducted fans, the respective turbine energised by ram air driving suction blowers by direct, or pneumatic, coupling.

Besides, a comparison on cycle efficiency only is not sufficient. What matters in the end for a long-range aircraft is not only the weight of the fuel but the weight of the power plant and total fuel.

Design studies on this basis indicate no marked difference between ducted fan engines and propeller-turbines, since on laminarised aircraft which are very economical in regard to fuel flow per hour the accent is more on power plant weight than on fuel weight.

There exists no fundamental reason why laminarisation should be confined to wings and tail surfaces. However, laminarising the body will entail very far-reaching consequences in the design of fuselages, for example, the elimination of windows, doors and a radical change in cockpit layout. It may entail having the main cockpit far aft with only a small cockpit (perhaps with prone position for the pilot) in the nose of the fuselage, to be used only for take-off and landing. View of the scenery in windowless fuselages could be simulated by camera-obscura effects, or special observation stations could be arranged at the rear end.

However, there is an alternative to laminarising the fuselage surface which might be more practical, although not quite so efficient.

The orthodox method of propelling a body through the air consists in producing a thrust T by accelerating a certain mass m of freestream air to a higher velocity $U' > U_0$.

With a jet the mass m is relatively small and U' is large. With a propeller m is larger and U' is smaller, hence for the same thrust kinetic losses $\frac{1}{2}m(U'^2 - U^2)$ are smaller for the propeller, and the Froude efficiency

$$\eta_F = \frac{2}{U'/U + 1}$$

is higher than for the jet. Due to the formation and separation of the boundary layer a wake is formed and inside this wake the total head is reduced. This causes the drag D, which has to be equalised by the thrust T.

We have, therefore, the "drag wake," where a negative flow velocity is superimposed upon free stream velocity and the "thrust wake," due to jet or slipstream, where a positive or super-velocity is added to free-stream velocity.

It is obvious that even with infinitely small energy contained in the thrust wake ($\eta_F = 1$), there still remains the loss of energy in the drag wake.

Supposing a system could re-energise the air in the turbulent boundary layer in a plane just ahead of the point where it separates at the rear end of the body, then there would be no drag wake and the horsepower required to perform the reacceleration would be much less than the shaft horsepower required by a propeller or ducted fan producing a thrust which equals the wake drag.

Obviously, there will be an efficiency of "no return" for such an accelerator mechanism. Preliminary studies have indicated that this limiting efficiency can be lower than that of a propeller.

Even with an imperfect acceleration which only approximately restores free stream velocity within the boundary layer thickness, substantial improvements are indicated over the conventional method which accepts the body wake as an unavoidable act of providence.

The usual criterion of Froude efficiency hardly applies in this case, when ideally no energy is left in the fluid.

It is more a form of recovering energy which has been lost due to friction and which has not been transformed into heat.

One might liken this form of propulsion to a rocket where the efflux velocity equals flight velocity. In the same way as a rocket, mass and energy is withdrawn from the body of the rocket ($\frac{1}{2}mv^2$), so is here the virtual mass of the body reduced by the reacceleration of stagnant boundary layer clinging to the body.

All the foregoing considerations aim at improving fuel eeonomy at cruising flight. However, there is also the need for thrust during take-off and climb, if the laminarised aircraft is to use conventional methods and not, for example, a form of direct lift.

The more cruising drag and thrust are reduced by progressive laminarisation, the more the ratio take-off to cruising thrust reaches uncomfortably large values, and the endeavour to substitute existing power plants by boundary layer propulsion must be tempered by take-off and climb considerations.

It is obviously uneconomical to carry an oversized power plant over the whole range, to the detriment of payload, the function of part of this power plant being restricted to a relatively short duration.

It would seem to be a better policy to have a cruising power plant tailored to suit cruising conditions with best economy supported by a second plant, specifically lighter and possibly of less economical fuel consumption and of shorter life to bolster up the take-off thrust supplied by the cruising plant. The Rolls-Royce "Soar" of exceptionally low specific weight exemplifies this type of take-off power unit.

The amount of thrust required for take-off can be minimised, as shown in No. I, by employing the suction blowers for the dual purpose of laminarisation and the provision of a high lift coefficient. Hence, the two forms of application of boundary layer control are complementary and interdependent on a laminarised aircraft.

Reduction in size of engines corresponding to the greatly reduced cruising thrust of laminarised aircraft (provided that deficiencies in thrust for take-off and climb are compensated by other means) will enable the designer to choose unorthodox engine arrangements. It may lead to the use of gas or air generator plants energising dispersed turbines to drive ducted fans and suction blowers situated in the most suitable positions on the aircraft.

Indirect reduction or elimination of form drag will thus result from the primary reduction of frictional drag coupled with an increased freedom to place the propulsion unit in the most favourable position and the gas or air producers in the most convenient place.

The recently disclosed experiments with the "Flying Bedstead" indicate the possibility of vertical take-off by means of direct lift from jets deflected vertically downwards.

The additional weight of jets producing a total thrust exceeding the all-up weight of the aircraft would probably be prohibitively large for conventional long-range aircraft where payload is only a small percentage of all-up weight, even if the lift engines are of very low specific weight.

The chances of applying direct lift are better for a highly laminarised aircraft than for a conventional aircraft, owing to greatly reduced fuel weight for the same range and payload. The additional weight of the lifting engines

* Director of Research, Handley Page Ltd.

† Or would have to be ducted outside the propeller disc area.

presents itself in highly concentrated form, i.e. at high density, which is more convenient than additional low density payload demanding increased stowage volume and wetted surface.

The possibility of replacing, either partially or totally, existing types of jet engines by a form of boundary layer propulsion in cruising flight has another aspect. Noise will be greatly reduced in view of reduced thrust coupled with reduced efflux velocity, a fact that may not only add to the comfort of air passengers, but may also have some significance in the field of military aviation.

This discussion of the demands on the power plant of a laminarised aircraft illustrate the point made at the beginning, namely, the need for integration of wings, body and power plant, which is essential to achieve the optimum results from the application of boundary layer control. This integration and the neutralising of drag at the source, so to speak, by suitably infused energy into the boundary layer will demand a very close and intelligent co-operation between aircraft and engine designers.

Exploitation of the finer potentialities of boundary layer propulsion may lead to a splitting up of power units into gas or compressed air generators and dispersed turbines to drive ducted fans.

However, even when neglecting these refined methods for the time being, existing types of conventional by-pass engines, which come nearest to the ideal type of power plant for a laminarised aircraft, are much too large to be suitable for aircraft of greatly reduced thrust requirements.

Taking as an example of a promising application of boundary layer control a four-engined civil air liner or freighter (25,000 lb payload) to serve the North Atlantic route (London-New York), scaled down units giving roughly 30 per cent of the thrust of a Conway engine would about fill the bill.

There is nothing in this line on the shelves as far as I know at present.

The alternative, i.e. scaling up the aircraft to meet the size of existing units, would lead to excessive sizes and weights.

This situation concerning the power plants for potential laminarised aircraft should be noted by the powers-that-be. Promotion of boundary layer control for the purpose of laminarisation is of no avail if the development of suitable engines is overlooked. We may find ourselves unable to harvest the fruits of our labours in the aerodynamic field, because of the lack of engines to power the aircraft of greatly reduced drag.

The Effect of Laminarisation on Performance of Aircraft

In view of the effect of surface roughness and sweep-back on transition, it would seem to follow that the highest cruising altitude would afford most favourable conditions for a laminarised aircraft due to the reduction with increase of altitude of the all-important parameter U/ν for a given cruising speed.

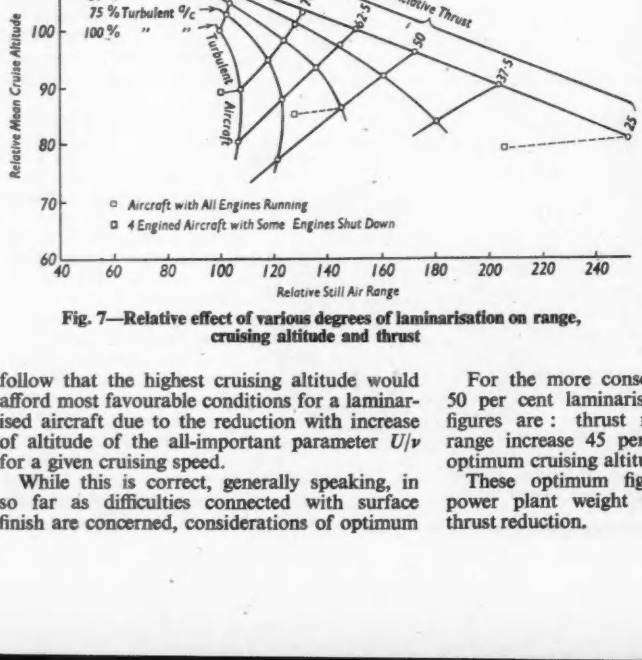


Fig. 7—Relative effect of various degrees of laminarisation on range, cruising altitude and thrust

While this is correct, generally speaking, in so far as difficulties connected with surface finish are concerned, considerations of optimum speed demand an equivalent reduction of induced drag when the frictional drag is lowered.

If reduction of induced drag is attempted by increasing the span of the wings, it will be found by weight analysis that the resulting increase of wing structure weight swallows up a good deal of the benefit that results from drag reduction due to laminarisation.

When comparing performance of a "turbulent" aircraft, i.e. an aircraft where the wings have transition at the leading edge and where a turbulent boundary layer exists for the whole wetted surface of the fuselage and tail unit with a laminarised aircraft of equal span and weight, it is found that progressive degrees of laminarisation necessitate a corresponding lowering of the cruising altitude for the laminarised aircraft and a simultaneous reduction of cruising thrust and power plant weight to achieve the greatest improvement of range for a given payload, or, alternatively, the optimum payload for a given range and fuel weight.

Fig. 7 shows the relative effect of various degrees of laminarisation on range, cruising altitude and thrust at optimum cruising revolutions per minute. All aircraft are of the same all-up weight (on take-off), carry the same payload at the same cruising speed, and are assumed to have the same wing area and aspect ratio.

For the laminarised aircraft suitable allowances have been made for extra weight, i.e. weight of suction plant, modifications to wing surface, ducting, and so on.

The basic aircraft, termed "turbulent" aircraft, is a four-engined transport for which detailed weight and performance data were available.

The range of this aircraft at its cruising altitude (100) is marked 100, and it will be noticed that the basic cruising altitude is somewhat above that for which range would be a maximum. In other words, the basic aircraft flies somewhat below optimum cruising speed.

This basic aircraft is now subjected to progressive degrees of laminarisation, assuming either that the same power plant is maintained, or that a progressive reduction of relative thrust and power plant weight takes place as frictional drag is reduced. Cruising speed is maintained constant.

It can be seen that progressive laminarisation without corresponding reduction of power plant results in relatively unimpressive increase of cruising altitude, as compared with that of the basic aircraft and with apparently no increase of range.

It should be noted, however, that an attempt to increase the cruising altitude of the "turbulent" aircraft by a corresponding amount could only be obtained with additional power plant and with substantial loss of range, assuming payload remains the same.

Fig. 8 indicates how substantial increase of range for the laminarised aircraft results if cruising altitude is lowered and power plant weight progressively reduced with increasing degrees of laminarisation.

For example, in the ideal case of an aircraft with complete laminar flow over the whole of its wetted surface, only one-quarter of the thrust of the "turbulent" aircraft will be required, range being about 150 per cent greater and optimum cruising altitude about 20 per cent less.

For the more conservative example of, say, 50 per cent laminarisation, the corresponding figures are: thrust reduction, 50 per cent; range increase 45 per cent, and reduction of optimum cruising altitude, 14 per cent.

These optimum figures are obtained with power plant weight reduced proportional to thrust reduction.

If the same power plant is carried by the laminarised aircraft as on the "turbulent" one, redundant engines being shut down for cruising flight, the remaining ones operating at optimum cruising revolutions per minute, the maximum range is reduced, as the dotted lines and square dots (Fig. 7) indicate.

A different approach to that discussed above would consist in designing *ab initio* an aircraft

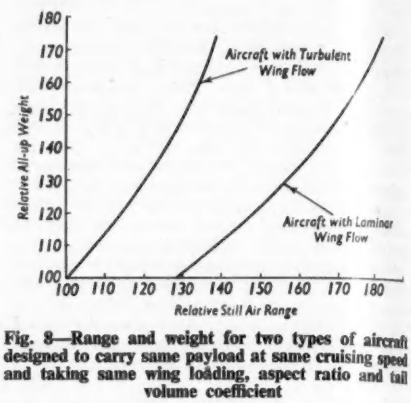


Fig. 8—Range and weight for two types of aircraft designed to carry same payload at same cruising speed and taking same wing loading, aspect ratio and tail volume coefficient

for the basic task of carrying a certain payload at a certain cruising speed over a given range, stipulating at the same time a certain landing speed.

The "snowballing" effect of initial differences of component weights—in this case the reduced weight for power plant and fuel systems for the laminarised aircraft and its greatly reduced fuel weight—is a well-known design phenomenon. Hence, it is not surprising that the aircraft with laminarised wings, carrying the same payload, at the same cruising speed, over the same range, will be substantially lighter and smaller than the equivalent "turbulent" aircraft.

If the range of the basic "turbulent" aircraft should already satisfy requirements—improvements due to lower specific fuel consumption can certainly be expected—the fuel saving due to drag reduction by laminarisation can be converted, of course, into additional payload.

Increase of low-density payload (passengers) necessitates an increase of stowage volume and thus of wetted body surface. A certain amount of stowage volume is gained due to the reduction of fuel and power plant, but the problem of laminarising the surface of the fuselage gains importance for such aircraft designed to carry a large payload of low density.

Outlook and Conclusions

Never before in the short history of aviation has the pace of development been so hot and re-orientation been so rapid.

No sooner have we begun to master problems of flight at high subsonic Mach numbers and in the transonic regime than the still more formidable tasks of supersonic flight loom ahead.

The question "Where do we go from here?" is uppermost in the minds of those who have to plan design and production for the coming decade and beyond.

In the military field the urge towards the attainment of high supersonic Mach numbers is all-powerful and overshadows all considerations of economy. This urge may lead us, with logical consequence, to the development of the guided missile, not only for defence, but also for offence.

The aim for civil aviation is primarily to fly more safely and more economically. The target for military aircraft is to fly faster and higher. These are two very divergent requirements. Hence, development of future civil aircraft will, in my opinion, follow separate and independent ways and remain governed by different laws. A repetition of the past, where the bomber used to be the pace-maker of the future air liner, would seem highly improbable.

There is too much tendency nowadays to transfer the speed fixation of the military into the realms of civil aviation.

Fundamentaliy, there is no improvement of

flight economy at supersonic speed; on the contrary, the increase of drag due to the shock waves is barely compensated by the improvements of efficiency of propulsion in comparison with flight at subsonic Mach numbers. The civil operator is attracted by the prospect of better utilisation of aircraft due to reduction of flying time. But the prospect for the aircraft constructor is to enter a rapidly shrinking market and to face ever-increasing and harder competition if this outlook should materialise.

Besides, supersonic flight is only in its infancy and formidable engineering problems have to be solved before flight at high supersonic Mach numbers over long distances will reach the standard of safety and regularity required for passenger traffic.

How does boundary layer control fit into this general picture?

The importance of laminarisation for military applications has obviously receded, at least for such aircraft which are to fly at supersonic speed, except perhaps when extreme range is needed and when strategic considerations permit part of it to be covered at high subsonic Mach number.

Long-range naval reconnaisance aircraft, submarine spotters and long-range transports should be able to benefit from the improvements in range and fuel economy and from the possibility of designing such aircraft at reduced size and all-up weight for a given range and load.

The importance of reduction in take-off and landing speed and the corresponding reduction of take-off and landing distances, due to the high life coefficients which are made possible by circulation control, for all deck landing aircraft and many other types of military aircraft, has already been stressed and needs no further emphasis. This applies equally well to civil aircraft, and particular interest exists for the development of aircraft of ultra-short landing or take-off distances to compete with the helicopter.

The general prediction is ventured that the bulk of passenger and freight-carrying aircraft will stay subsonic for a long time to come. There may thus be a state of co-existence of the supersonic and the subsonic flight regimes. In the subsonic regime laminarisation through boundary layer control and re-energisation of the boundary layer remain the only fundamental aerodynamic possibilities to improve the economy of flight.

To translate the now well-founded and proved potentialities of boundary layer control, either for lift increase or laminarisation, into engineering reality, emphasis of research must shift from the more academic and theoretical treatment and from wind tunnel testing to flight trials and to the development of practical engineering solutions. Only thus can the necessary "know-how" be gained, this essential link between experiment and practical application.

Free Gold Extraction from Pulped Ore

A RIFFLE concentrator belt, which adapts the old-established method of recovering free gold from pulped ore by passing the pulped stream over corduroy tables, has been recently introduced in the recovery plants of Brakpan Mines, Welkom Gold Mining Company, Western Holdings and President Brand Gold Mining Company. The merit of this method of concentration, it is stated, lies in the fact that it recovers, during milling, relatively large particles of free gold if they are present. These coarser particles would take longer than fine particles to dissolve in cyanide solution, and would thus retard this stage of gold extraction.

The concentrator comprises a continuous rubber belt, 5ft wide and about 9ft long, passing round two rollers and inclined to the horizontal. The pulp stream is directed laterally on to the raised end of the belt, which moves continuously against the stream. A jet of water directed towards the underside of the belt washes off the gold collected in the riffles. The overflow from the belt goes back into the milling circuit, and the concentrate is pumped directly to the amalgamation plant. Each concentrating unit is completely enclosed.

Marine Main Steam Control Unit

THE drawing reproduced below shows the arrangement of the combined main steam control unit which was exhibited at the Scottish Industries Exhibition by Cockburns, Ltd., Cardonald, Glasgow, S.W.2. A number of these units have been made by the firm for installation on "Esso" tankers, and the one shown in the drawing is designed for use with steam at a pressure of 900 lb per square inch and a temperature of 900 deg. Fah.

The compact layout of the valves on a heavy cast steel manifold with integral support brackets saves installation space and gives easy accessibility for manipulation purposes. On this manifold are mounted a 6in ahead turbine regulating valve, a 5½in astern turbine regulating valve, a 5½in astern turbine shut-off valve, a 6in self-closing emergency steam valve and a steam strainer.

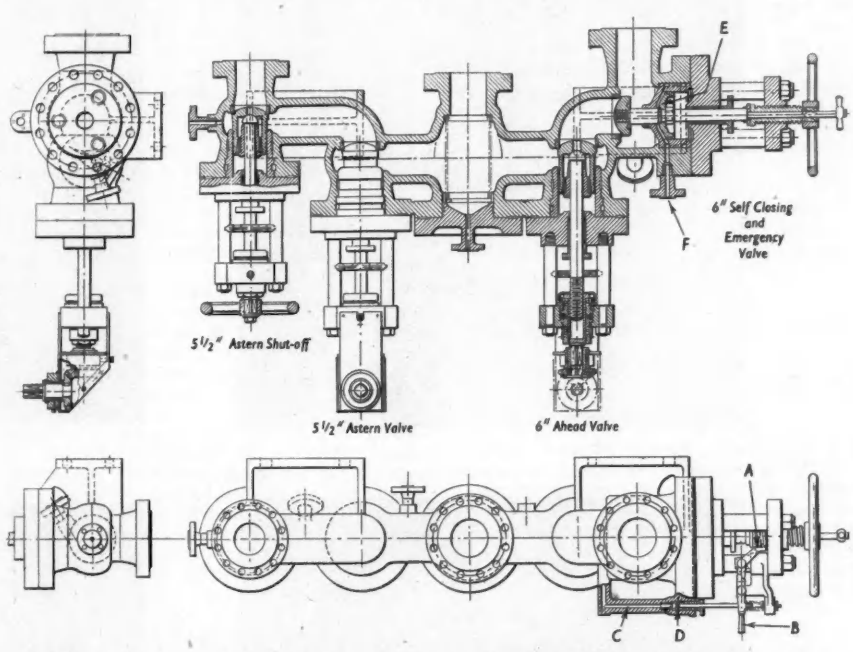
The steam strainer is designed to reduce as far as possible the pressure drop. It incorporates a stainless steel wire-woven grid which has been found to give a very good rectangular converging diverging nozzle imparting a streamline flow effect to the steam.

The two 5½in astern and the 6in ahead valves are of the maker's single-beat balanced design and in them the pressure builds up in the top of the piston to load the valve down in the shut position. When the hand-wheel is turned to open the valve the initial movement of the spindle lifts the balancing valve formed by the top of the spindle. This exhausts the pressure from the top of the piston and brings the valve into a state of balance, so that further movement in opening or closing the valve calls for a minimum of effort.

On a manœuvring valve in marine applications, where sudden operation may be called for, it is essential that the valve can at all times be readily operated without chance of its locking in any position. This locking can arise whilst the valve is shut due to the differential expansion of the various materials at varying temperatures. It can also arise as a result of flywheel action of the handwheel. To overcome this difficulty the crosshead is fitted with a spring buffer in the form of Belleville washers. These washers, although they require a heavy load for deflection, have sufficient elasticity to prevent the locking action taking place. The crosshead is so designed that the springs allow for a small axial movement in each direction when under load, but even should a spring be fractured the valve operating gear would continue to function as an ordinary solid crosshead with but a small backlash on the regulating nut.

The 6in, piston-operated, self-closing, bulkhead valve is designed to close automatically when the balance of pressure on the piston is upset. It comes into effect to shut off the supply of steam in the event of an emergency brought about by any one of the following conditions: forced lubrication pressure failure; action of the governors in the event of turbine over-speeding; excessive end movement of the turbine rotor; operation of a hand emergency control lever, and loss of vacuum.

The operation of the valve can be followed with reference to the drawing. When the regulating screw is moved back an inclined plane *A* on the screw operates the lever *B* to admit a supply of steam through the passage *C* and a needle valve *D* to the back of the piston *E*.



Marine main steam control unit, incorporating ahead and astern turbine regulating valves, astern turbine shut-off valve, self-closing emergency valve and steam strainer

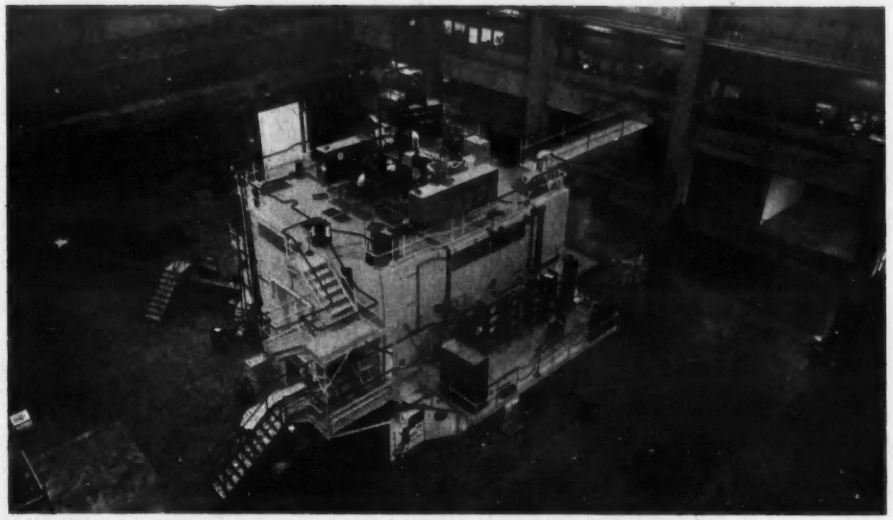
The accumulated steam leaks past the piston rings to the front of the piston, which moves back to open the main valve. The steam at the back of the piston serves as a cushion to prevent damage caused by too rapid opening of the valve. To close the main valve the needle supply valve is held open by its handle whilst the regulating screw is rotated.

The front of the valve chamber is connected to an oil-cylinder-operated pressure-breaking relay valve through the connection *F*. The pressure of oil maintaining the relay valve controls a valve through which the pipe from *F* exhausts. Thus, so long as the oil pressure is maintained the pressure in the front of the piston of the main valve is sufficient to keep the valve open. Loss of this pressure—due to failure of the turbine lubricating system or action of the governors—opens the front of the piston cylinder to exhaust, and the main steam pressure behind the piston moves it forwards to close the valve. Excessive end movement developing in a turbine rotor allows the governor bush to move and uncover a port through which the oil pressure is released to close the main valve as before.

Operation of the hand emergency control also shuts off the pressure from the forced lubrication system to the relay valve.

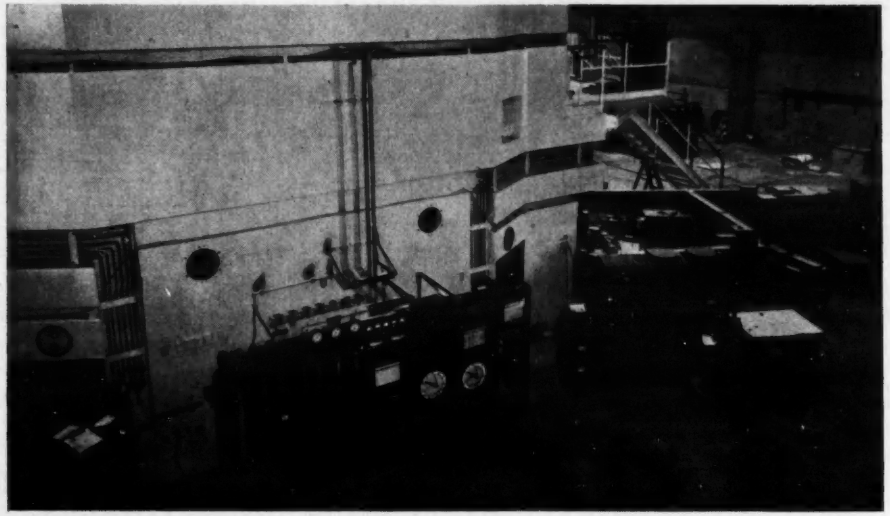
A diaphragm control unit connected to the condenser is deflected when the vacuum falls below a predetermined limit, and this unit through levers opens its associated steam control valve and relieves pressure from the front of the main valve piston to close the valve.

CONTROL SYSTEM OF MATERIALS TESTING REACTOR

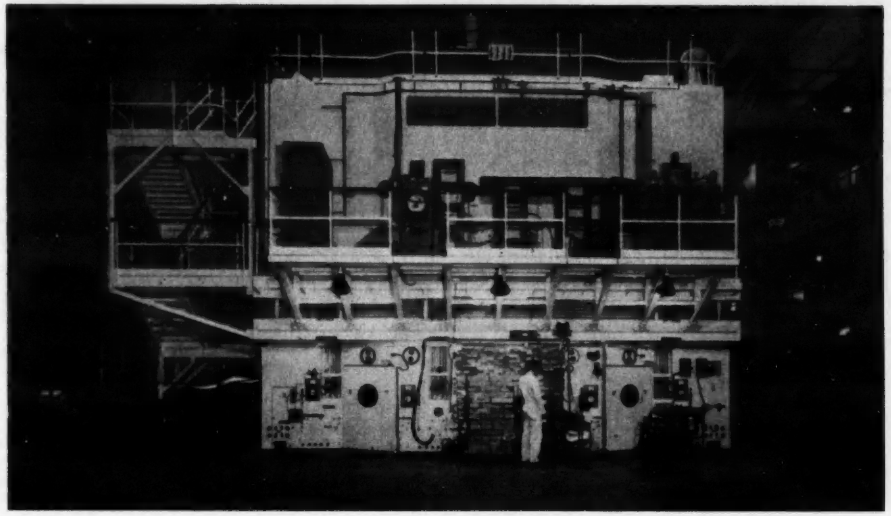


Reactor with control room on second floor balcony at end of bridge

Interior of reactor control room



West face of reactor with neutral crystal spectrometer in the foreground



North face of reactor showing horizontal beam hole openings and concrete shielding blocks

Materials Testing Reactor of the U.S. Atomic Energy Commission

BY OUR AMERICAN EDITOR

No. II—(*Continued from page 720, November 19th*)

The Materials Testing Reactor (MTR) of the U.S. Atomic Energy Commission has been in operation at its full rated power of 30MW since May, 1952. The pile was designed and constructed by the A.E.C. primarily to provide facilities for testing materials in radiation fields of very high intensity. The MTR is a thermal neutron reactor using enriched uranium as fuel, ordinary water as both moderator and coolant and beryllium as reflector. It produces average neutron fluxes of 2×10^{14} thermal neutrons per square centimetre per second and 1×10^{14} fast neutrons per square centimetre per second, and is said to have the highest thermal neutron flux of any pile now in existence

THE general scheme for controlling the reactor may be described as a combination of manual control by the operator and automatic control from the instrument signals, so that, particularly during start-up, the operator and the instruments serve as mutual checks on each other. The motion of the shim safety rods to cause increased reactivity of the reactor requires the permission both of the operator and of various automatic devices and interlocks. However, an action tending to decrease the reactivity can be initiated by either the operator or several automatic devices independently. The action of the various "scram" circuits, i.e. those that shut the reactor down irreversibly in the event of an emergency, is entirely independent of the normal control and interlock circuits. Thus, it may be said that the reactor is subject to effects of the control rods, auxiliary facilities, and certain disturbances. The reactor, in turn, affects certain instruments that produce information to be transmitted to the operator and to the control system. The operator and the control system also receive information from selsyns and other indicators of rod position or rod motion. On the basis of the information received, taken together with the operator's actions or instructions, the control system transmits to the motors or to the magnetic clutches appropriate control signals. The motors or magnetic clutches cause corresponding rod motions, which affect the reactor. Thus, the main control loop is a closed path. Views of the control system are reproduced here.

The two functions of the control elements are the safety function and the regulator function, the former being to guard against danger to the reactor and personnel and the latter to provide for start-up and shut-down as well as for the maintenance of a satisfactorily close regulation of the neutron flux over the required range of operating levels. The safety and protective elements consist of those which warn the operator that action is necessary and those which automatically limit the speed of the control rod, reduce the power level, and shut the reactor down. The latter three functions are accomplished, respectively, by "period" control, a motorised rheostat, and the release of magnetic clutches on the shim safety rods. Period control is based on an electronic device that measures the time derivative of the logarithm of the neutron flux. It is used to prevent short reactor periods. A reduction of the power level to about 1 per cent of the normal operating level is valuable in emergencies in which the more drastic "scram" might not be justified and is brought about by signals not only from the instruments indicating neutron flux, but also from the monitors on cooling water activity, cooling air activity, experimental facilities, instrument elements, &c. "Scram" signals come from instruments indicating the neutron-flux level and from a few critical monitors such as those measuring the cooling water flow. In addition to these devices a group of interlocks is used to serve as a step-by-step check on the operator to prevent serious consequences from mistakes.

The regulating requirements are met by a servo-mechanism which controls the motion of the regulating rod, whose position in turn calls for the withdrawal or insertion of the shim rods. The regulating rod itself controls about 0·5 per cent of the reactivity for purposes of fine regulation. Although one regulating rod is sufficient for the control of the reactor, a standby rod is provided, and there are four possible locations for these rods provided in the reactor. These locations are situated in the beryllium reflector adjacent to the active lattice. Each rod is 1½in in diameter and contains a 23in long centre section which has cadmium sandwiched in stainless steel tubing. Guides are provided in the upper and lower grid supports. The total weight of the rod and connecting shaft is approximately 55 lb. The rod is driven by a low-inertia, high-starting-torque d.c. motor through a rack and pinion mechanism which is integrated with the rod.

There are eight spaces provided in the reactor lattice for shim safety rods, although all need not necessarily be used. These shim rods are driven mechanically by a worm drive and reversible three-phase induction motors which are remotely controlled by electrically and mechanically interlocked reversing contactors. The drives are furnished with upper and lower limit switches. The advantage of the induction motor is that no accident can make it run in excess of synchronous speed; therefore, the danger of overspeed withdrawal of shim safety rods is eliminated. No brakes are required during reversal since the drive mechanism utilises the self-locking property of a worm gear.

To provide the "scram" feature for the shim safety rods, a magnetic coupling between the vertical lifting shaft and the rods is used. It comprises a bi-polar or horseshoe electromagnet. Its lifting capacity is adequate to support the rod against the static and dynamic forces imposed by the high-speed cooling water surrounding and passing through the shim safety rod. The magnet is wound with 3500 turns of fine wire so that a current of 100mA. will hold a load of 500 lb. It releases a 600 lb load held at 140mA. in 15 millisecs or less. The current is supplied by a vacuum valve which releases the magnet when the grid becomes less positive. The time lag in the release of the shim rod by the magnetic coupling is short enough, so that if the operator should inadvertently withdraw the shim rods at their maximum rate, with the reactor "super-prompt" critical, the chain reaction still would be safely stopped by the dropping of the shim rods themselves.

A period meter has been developed which gives a "scram" signal if the period is less than one second, and it causes the insertion of the shim rods by means of their motors when the period is less than five seconds. The design of the safety "scram" circuits is such that they give an alarm in the event that they are not in perfect operating condition. These alarms indicate not only failure, but also incipient failure and the point where failure occurs or is likely to occur. The shim safety rods are constructed to bring fuel sections into the lattice as they are raised. They have a cadmium sheet in the upper section, and this section will reside in the reactor when the rods rest in their lower shock absorbers. Each rod is extended at the top and the bottom by square hollow stainless steel sections. The top of the rod forms the armature for the magnetic clutch, and the bottom is formed into a tapered plunger. On an emergency release of the rod the energy resulting from the fall is transferred to water forced out of a dashpot by the tapered plunger. Graphite-faced guides with roller bearings are mounted about 3ft above and below the active lattice in guide support grids and are lubricated by the cooling water. The motors, drive mechanisms, position indicators and limit switches associated with both the regulating and the shim safety rods are situated on top of the reactor tank plug. The dashpots are situated in the bottom of the reactor tank, and the magnetic clutches work under water inside the reactor tank.

Control Instrumentation

The neutron-flux signals for operating the control circuits come from ten to fourteen instruments situated in the ten instrument holes which are provided in the reactor structure. Three ionisation chambers are reserved solely for the safety function to furnish "scram" signals at 1·5 to 3 times the reactor operating level and to furnish a slower signal to initiate a reversible reduction of the operating level. Other signals provide either a visual indication to the operator or signals to the servo-mechanism and other automatic devices. For visual indication from the operating level to 10^{-5} of the operating level, a direct-reading galvanometer is available. Another galvanometer shows the logarithm of the intensity factor from the operating level down to 10^{-11} of the operating level. In the lower part of the range the signal arises from a fission chamber and a counting-rate meter. There are three groups of instruments furnishing information to the operator and to the control system: (1) the reactor instruments measuring neutron flux or power level; (2) the rod-position and motion indicators; and (3) the instruments for the auxiliary facilities.

It is necessary to make a rather arbitrary distinction between reactor instruments and instruments on the auxiliary facilities, particularly on the cooling water. Reactor instruments include radiation instruments measuring the neutron level in the reactor and the radioactivity in the water, temperature instruments measuring the neutron level in the reactor and the radioactivity in the water, temperature instruments measuring the distribution of exit-water temperature across the active lattice and temperatures in the thermal and biological shields, and Pitot tubes measuring the distribution of water flow across the bottom of the fuel assemblies. The reactor radiation instruments are listed in the following table:—

Instrument	*Use*
Parallel - circular - plate ionisation chamber	Safety and servo signals
Compensated ionisation chamber	Logarithm of neutron flux and period signal; galvanometer signal
Fission chamber, 12ft travel	Counting rate signal
Air wall ionisation chamber	Water-flow N^{16} monitoring
Water-monitor ionisation chamber	Water sample monitoring
Boron thermo-piles ...	Neutron flux in graphite indication

The parallel-circular-plate ionisation chambers are designed, constructed and placed in the reactor so as to give a high-speed response to changes in neutron flux coming from the core of the reactor. The active section consists of a set of graphite discs, each of which is coated on both sides with B^{10}. Alpha particles are emitted by the $B^{10}(n, \alpha)Li^7$ reaction when neutrons bombard these discs. These alpha particles cause the ionisation which the chamber measures. The thickness of the boron coating of 0·3 milligrammes per square centimetre on the graphite discs was chosen so as to give a maximum ionisation current of about 50 micro-amperes at an operating flux of 10^{10} neutrons per square centimetre per second. The chambers cannot be placed as near to the reactor tank as would be desirable because of the high neutron flux. They are situated in holes, looking directly toward the tank, with collimating boral sleeves ahead of the chambers to enhance their inherent directional sensitivity to flux directly from the tank. With this arrangement the major delay is the time for neutrons to

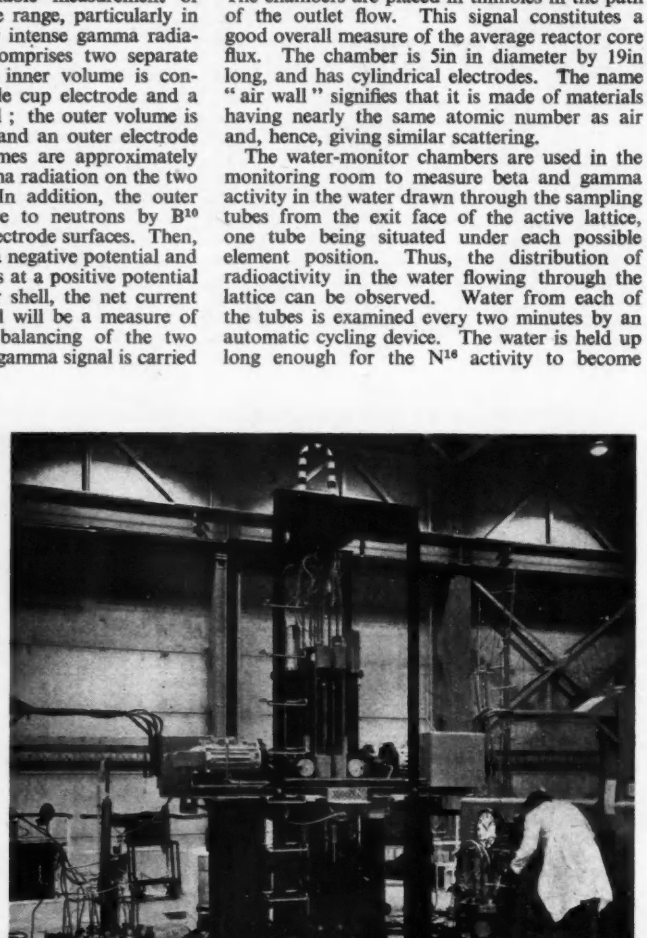
get from the core through the tank and into the graphite.

The compensated ionisation chamber is designed to give a reliable measurement of neutron flux over a large range, particularly in the presence of relatively intense gamma radiation. The instrument comprises two separate chamber volumes. The inner volume is contained between a movable cup electrode and a fixed inner electrode shell; the outer volume is between this inner shell and an outer electrode shell. As the two volumes are approximately equal, the effects of gamma radiation on the two should also be equal. In addition, the outer volume is made sensitive to neutrons by B^{10} coatings applied to the electrode surfaces. Then, if the cup electrode is at a negative potential and the outer shell electrode is at a positive potential with respect to the inner shell, the net current carried by the inner shell will be a measure of neutrons alone. Close balancing of the two volumes to obtain a zero gamma signal is carried out by moving the cup electrode, thus varying the inner volume.

The fission chamber is designed to give neutron measurements at low flux levels. A brass shell carries a nickel liner which has a coating of U^{235} on its inside surface. A central anode rod of commercially pure aluminium, ¼in in diameter, is supported on a coaxial connector. The neutrons absorbed in the U^{235} produce fission fragments which ionise the gas in the chamber. The voltage pulse thus created by each fission is amplified and counted. These fission pulses are large and can be counted separately from the lesser currents due to alpha or gamma radiation, i.e. the neutron flux can be accurately measured even in the presence of intense gamma radiation. By using argon gas, a short, sharp pulse may be obtained. However, the chamber performance is then very sensitive to gas impurities and to supply voltage; to minimise these difficulties, the argon is deliberately mixed with about 5 per cent carbon dioxide. Under these conditions pulses are distinguishable up to a limiting rate of nearly 1,000,000 per second. The counting rate meter used with the fission chamber, however, has a useful range from 1 to 10^4 counts per second, and this is, therefore, the working counting range of the complete instrument. To increase the neutron-flux range of the instrument, provision has been made for moving the chamber over a maximum distance of 12ft, from outside the top thermal shield to a point well inside it. This travel corresponds to an estimated change in sensivitity of 10^7. At the innermost position the minimum flux to be expected would be about 10^3 neutrons per square centimetre per second corresponding to 10 counts per second. The maximum flux at the inner position would be 10^{13} neutrons per square centimetre per second and at the outer position about 10^6 neutrons per square centimetre per second, corresponding to 10^4 counts per second, the upper limit of the counting rate meter. In view of this range the fission chamber is used at three established positions in its instrument hole, motion from one to the other giving a neutron-flux range multiplication of about 3×10^3, which is within the counting rate range of 10^4 counts per second. The means of moving the chamber is semi-automatic and is tied in with the control circuitry.

The air wall ionisation chamber is used to measure the energetic gamma activity of N^{16} formed in the O^{16} (n, p) N^{16} process by the neutron bombardment of the cooling water. The chambers are placed in thimbles in the path of the outlet flow. This signal constitutes a good overall measure of the average reactor core flux. The chamber is 5in in diameter by 19in long, and has cylindrical electrodes. The name "air wall" signifies that it is made of materials having nearly the same atomic number as air and, hence, giving similar scattering.

The water-monitor chambers are used in the monitoring room to measure beta and gamma activity in the water drawn through the sampling tubes from the exit face of the active lattice, one tube being situated under each possible element position. Thus, the distribution of radioactivity in the water flowing through the lattice can be observed. Water from each of the tubes is examined every two minutes by an automatic cycling device. The water is held up long enough for the N^{16} activity to become small; therefore, the observed activity is either that induced by the flux in the demineralised cooling water or it is evidence of a fission break (a rupture of a fuel element) in the core.



Top plug of reactor with control rod driving mechanisms

The boron thermopiles are used to provide an additional check on the neutron-flux level. They are all situated in the graphite at the same horizontal level. These instruments consist of a large number of thermocouple junctions in series, alternate junctions being coated with boron. The coated junctions become warm owing to the absorption of neutrons, thus yielding a net voltage which is a measure of neutron flux. Each instrument case is about ½in in diameter by 6in long.

In addition to the above reactor instruments, all of which measure radiation, there are various temperature and water-flow measuring instruments. Each of the sampling tubes under the fuel element positions is actually part of a triple-function assembly: sampling tube, Pitot tube for flow measurement, and thermo-couple for water temperature measurement. The knowledge of the distribution of water flow, velocity and temperature is of obvious value in operating a reactor. There are also numerous thermometric devices used for observing temperatures in other parts of the reactor. The most important of these, from the control standpoint, is the pair of thermo-couples in the inlet and outlet water lines, measuring the temperature rise, which is then multiplied by total water flow to give power absorbed from the reactor. A Venturi flowmeter feeds the signal to a flow recorder, and the thermocouples feed a differential temperature recorder. Impedances in these recorders are connected in a bridge circuit in such a way that the bridge output is proportional to the product of the two signals. The detector for this bridge is thus the power level recorder.

Certain auxiliary facilities are of importance in operating the reactor and therefore require indicating devices. The process water which cools the reactor is perhaps the most important auxiliary facility. Undue changes in temperature or flow of this water can result in just as serious damage to the reactor as undue changes in neutron level. The water level in the main tank, or "working reservoir," is guarded with automatic safety actions. "Scrams" or setbacks are automatically caused by any dangerous changes in flow, temperature or quantity of cooling water. In addition, the water system is provided with sundry alarms and recorders. Most of these will engage the attention of personnel stationed in the process water control and instrument centre, and will receive only marginal attention in the reactor control room proper. As far as cooling air is concerned, the operator is warned by alarms on the pressure and flow of air and also on the radioactivity in the air stack. In order that reactor operation may be as free as possible from the effects of transient disturbances or outages occurring on external power lines, electrical power for the control system is obtained from a special supply. This supply consists of two alternators operated from storage batteries which are kept charged by two converters. In normal operation, one alternator would supply the instrument bus voltage, and the other alternator would supply the relay bus voltage.

Adoption of International Nautical Mile

On July 1, 1954, the National Bureau of Standards began to use the International Nautical Mile in lieu of the U.S. Nautical Mile. This decision, replacing the U.S. nautical mile of 1853·248m (6080·20ft) by the International Nautical Mile of 1852m (6076·10333ft), confirms an official agreement between the U.S. Secretary of Commerce and the U.S. Secretary of Defence to use the International Nautical Mile within their respective departments. The British and the U.S. nautical miles were each derived by taking 60 nautical miles per degree, but the values adopted were not the same. The nautical mile adopted by the British Admiralty equals 6080 British feet, while the U.S. nautical mile has had the adopted value of 1853·248m, from which the equivalent 6080·20 U.S. feet has been derived. The British foot is shorter than the U.S. foot by 1 part in 400,000, an amount which is of no importance in the ordinary transactions of everyday life, but which is very important in precise measurements.

In 1929 the International Hydrographic Bureau obtained an agreement from a large number of countries to adopt a value of 1852m for the nautical mile, the unit thus defined to be called the International Nautical Mile. However, at the same time, Great Britain, the U.S.S.R., and the United States did not accept this value, each country preferring to retain the nautical mile to which it had been accustomed. Finally, in 1953, an informal group from the Department of Defence and the Department of Commerce considered a proposal for the international standardisation of abbreviations for the knot and the mile. At this meeting the general situation regarding the nautical mile was discussed, and the belief was expressed that a change from 1853·278m to 1852m would not affect nautical charts, the calibration of navigational instruments or navigation. Because there seemed to be no sound reason why the International Nautical Mile should not be adopted in the United States, the Departments of Commerce and Defence agreed to accept this value.

Aluminium Compressed Air Main.—A 6in compressed air main using some 8500ft of aluminium pipe is being used to supply air to the working faces in the construction of the tailrace of the Roanoke Rapids dam. By using 20ft lengths of pipe, weighing only 27 lb, and fitted with quick coupling devices, the main is being extended as work proceeds.

Industrial and Labour Notes

Research and Industrial Productivity

On Monday last, there was a conference in London to discuss the subject of research and industrial productivity. It was organised by the Department of Scientific and Industrial Research in collaboration with the British Productivity Council and the British Institute of Management. Most of the deliberations at this conference were in private session, but it is hoped that a full report of the proceedings will be made available in the near future.

At the opening, the conference was addressed by Sir Ben Lockspeiser, F.R.S., secretary of the D.S.I.R., who said that, apart from the material benefits to be had from increased productivity, there was something else which in the long run might prove to be the more significant factor. The great productivity campaign now in progress throughout the country was bringing all concerned in industry closer together for a common purpose. Nothing much could be achieved otherwise, Sir Ben remarked ; it was important enough to-day, but it would be doubly important tomorrow. The word revolution, Sir Ben continued, was often used lightly, but, in the opinion of many shrewd and competent observers of the industrial scene, a second industrial revolution was stealing on us as quietly as the first which this country launched on the world in the eighteenth century.

The fully automatic factory, Sir Ben went on to say, was on its way. The oil, chemical and food processing industries had been steadily moving away from batch processing to continuous operation embodying a measure of automatic control, and the metal using industries in their engineering shops were moving in the same direction, the logical end of which was in the fully automatic plant or factory. The fully automatic electronic digital computer was emerging from the research laboratory as a master mechanism to integrate and control automatically the discrete steps hitherto involved in the processing industries and in the manufacture of engineering products. There was a good way to go, Sir Ben observed, before highly complex techniques such as these could be reliably and generally established, but this was the way things were going, and there was not likely to be much or perhaps any advantage from the revolution in technology without a new synthesis within the living body of industry. But the changes required by technology were apt to conflict with habits of work and ideas of management. Technology to-day was calling an expensive tune and, Sir Ben said, it would not benefit anybody, either in private industry or in any form of State industry, to invest the large capital required for the new developments that were already upon us if the plant could not be operated fully and economically.

Some of the old conceptions still current on both sides of industry, Sir Ben suggested, were quite out of step with modern technology. Employers' federations, trades unions, everybody in fact, he said, would have to do a lot of fresh thinking, on human as well as technical problems, if an old, traditionally minded democracy such as ours was both to preserve the freedoms it cared for and earn its living in a competitive world. In order to ensure that research programmes had the right emphasis and that the results were applied successfully, the needs of industry and the conditions under which it operated must be studied more closely. It was necessary also, Sir Ben added, to think not only in terms of science, but of costs and economics, and in terms of human values.

Steel Production and Supplies

On Monday last, several questions about steel production and supplies were addressed, in the House of Commons, to the Minister of Supply, Mr. Selwyn Lloyd. He was first of all asked "what restrictions, allocations or rationing arrangements" were maintained by his department on steel, steel products and tinplate ? In reply, the Minister explained that tinplate was the only iron and steel product, the distribution of which was still under statutory control by his department. The cost of the control, the Minister said, was less than £6000 a year, and it would be removed as soon as the supply position justified it.

The Minister was then asked about lengthening deliveries to industry of steel and rolled and rerolled products, in view of increasing industrial output. The Minister said that he was aware that difficulties had been experienced recently in meeting fully the demands for certain descriptions of finished steel, and the matter was one which was receiving the constant attention of the Iron and Steel Board. British steel production last year, the Minister continued, was equivalent to 17,610,000 ingot tons. This year it was expected to be approximately 18,500,000 ingot tons, and in 1955, production was likely to be 19,250,000 tons or possibly more. The present indications were, Mr. Lloyd said, that certain kinds of finished steel would have to be imported in 1955, but the quantities should be only marginal. He added that full regard was being paid to the expanding demands of industry, and said that the total production of sheet steel this year would be about 2,000,000 tons, or 11 per cent greater than in 1953. It was hoped that the production of sheets would continue to increase.

Industrial Estate at Woolwich Arsenal

In our issue of October 22nd last, we recorded that the London County Council had been recommended by its town planning committee to complete the purchase of a site of 118 acres at Woolwich Arsenal with a view to its development as an industrial estate. It was urged that the primary objective in operating the estate should be to promote the London Development Plan by facilitating the relocation of London firms. To contribute to the absorption of local labour, however, and to get the estate off to a good start, it was realised that it might be necessary, especially at the outset, to consider the claims of other firms.

Last week, the L.C.C. accepted a further report from the town planning committee, which referred to an application by Ford Motor Company, Ltd., for a lease of buildings and land on the estate at an early date. The buildings are at the western end of the proposed estate and the total area of land concerned is about 7 acres. The town planning committee felt that a lease to this firm would ensure a good start to the future development of the estate. The class of industry proposed was capable of providing suitable employment for persons who might become redundant on the contraction of the Government ordnance factory, and Ford Motor Company, Ltd., the report stated, had indicated that it was anxious to co-operate in that matter as far as practicable. The town planning committee had decided, therefore, that, subject to the necessary consents, a suitable lease of the land and buildings should be granted for a period of twenty-one years, with an option to the company to terminate at the end of the seventh or fourteenth years. Occupation by Ford Motor Company, Ltd., the town planning committee stated, would take place gradually from about the end of January next.

Industrial Investment

The annual general meeting of members in the northern region of the Federation of British Industries was held at Newcastle upon Tyne on Tuesday. It was addressed by Sir Harry Pilkington, president of the F.B.I., who stressed the necessity for "turning more and more to creative promotional work in this dynamic world."

Amongst other matters, Sir Harry made reference to industrial investment, not overseas, but at home. Industry, he said, had so much to do with so few pairs of hands, and the opportunities ahead were enormous, but only if we prepared for them in advance. Industrial investment, Sir Harry asserted, was going on apace in all our main competitor countries, but, he added, we had not been expanding as quickly as some of our competitors. Industry as a whole, however, Sir Harry continued, was going to expand, and industrial production was going to rise steadily over the next few years. Plans announced for the motor, chemical, steel and many other industries proved that, but, he urged, expansion must be balanced.

Enlarging upon that theme, Sir Harry went on to say that industry could not permanently get on with the same offices as it had twenty years ago ; it certainly could not get on with the same amount of power, nor of coal. Nor, Sir Harry remarked, could we transport double our traffic on the same roads. The growth of private industry meant a parallel expansion in the ancillary industries and services, for all were linked. But for too long, Sir Harry said, we had applied a different criterion to expenditure on roads, for the excellent reason that public expenditure was too high. That approach, however, was no longer realistic, for in this exporting country, Sir Harry commented, all our industrial centres were within 100 miles of the country's great ports. Roads must be the industrial conveyor belts from the factories to the ports and, Sir Harry emphasised, "they must be large enough, straight enough, and clear enough to serve that purpose." The national return from any given expenditure on roads was difficult to show in exact statistics, and was therefore, Sir Harry thought, often wildly exaggerated by enthusiasts to the detriment of their own case. But, Sir Harry went on, whatever it might be now, in a few years' time congestion resulting from industrial expansion would be such as to slow down industrial output and increase costs to a point where we were no longer competitive. A real programme of roads linking the docks with the factories would take longer than ten years to complete, but the expenditure would pay the nation. As soon as labour and materials were available, or sooner, Sir Harry urged, the actual work on these "conveyor belts," which were the necessary corollary to our own industrial investment, must proceed, so that in ten or twelve years from now our roads, our power supplies, and our factories, large and small, were geared to deal with a production half as large again as to-day's.

West European Steel Output

The United Nations Economic Commission for Europe has shown in its latest bulletin of steel statistics that, in the third quarter of this year, the annual rate of crude steel production was around the 1952 record rate in Belgium, France and Luxembourg, and that elsewhere in Europe new production records were being achieved. Steel production in the United Kingdom in August and September was at the highest annual rates ever recorded for those months, and in Western Germany the previous highest annual output figure was exceeded. For purposes of comparison, the bulletin shows that steel production in the U.S.A. in the third quarter of this year fell to 72 per cent of last year's annual rate, although, it is stated, output "now appears to be increasing once more."

About foreign trade in steel, the bulletin says that in the first seven months of this year the annual rate of exports of finished steel from Belgium, Luxembourg and France closely approached the high rate achieved in 1951. In the United Kingdom, Western Germany, the Netherlands and Austria, exports achieved their best post-war annual rates. Finished steel imports during the first seven months of this year by Western Germany, the Netherlands, Sweden, Italy and France were, on average, above the annual rates of any of the post-war years. Imports into Switzerland, Belgium and Luxembourg did not show any appreciable change, but it is stated, finished steel imports by the United Kingdom were lower than in any year since 1947 and 1948.

Notes and Memoranda

Rail and Road

ROAD ACCIDENTS.—The Ministry of Transport says that road casualty figures for October show an increase of nearly one-fifth compared with a year ago. The provisional total is 22,326, which includes 485 fatal injuries, an increase of 39; 5298 serious injuries, an increase of 658, and 16,543 slight injuries, an increase of 2810. The final figures for September give a total of 22,614, which was 2215 more than in September last year, although the number of those who died, 425, was seven less. The seriously injured rose by 423 to 5408, and the slightly injured by 1799 to 16,781. Compared with a year ago, casualties to drivers other than motor-cyclists, increased by 599, or more than one-third. Casualties to pedestrians were 7 per cent higher.

Miscellanea

"VALVE RETAINER AND VALVE DATA."—A booklet giving data on thermionic valve retainers, together with a cross index, has been published by Electrothermal Engineering, Ltd., 270, Neville Road, London, E.7, and copies of the booklet can be obtained from this address.

LYMPNE AIRPORT CLOSED.—Lympne Airport, which was established under defence powers in 1917, closed as an aerodrome for public use on October 31, 1954. Former owners or their successors have been given an opportunity of buying back their land, but land not so bought back will be offered for sale by tender.

MINING RESEARCH.—A research report describing the research carried out during the years 1950–53 at the Royal School of Mines has now been published by the Imperial College of Science and Technology, South Kensington. The report embodies contributions from the five sections of the Royal School of Mines, namely metallurgy, mineral dressing, mining, mining geology, and oil technology.

AWARD OF ROYAL MEDALS.—Her Majesty the Queen has been graciously pleased to approve recommendations made by the Council of the Royal Society for the award of the two Royal Medals for the current year to Sir John Cockcroft, K.C.B., C.B.E., F.R.S., for his distinguished work on nuclear and atomic physics, and to Professor H. A. Krebs, F.R.S., for his distinguished contributions to biochemistry.

INDUSTRIAL ASPECTS OF AIR POLLUTION.—A conference on "The Industrial Aspects of Air Pollution" is to be held at Harrogate on Wednesday and Thursday, December 8th and 9th. It is being arranged by the Combustion Engineering Association, and the opening address is to be given by Sir Hugh Beaver, chairman of the Air Pollution Committee. Full particulars of the conference can be obtained from the Combustion Engineering Association, 6, Duke Street, St. James's, London, S.W.1.

WHITWORTH SCHOLARSHIPS, 1955.—The Ministry of Education has published, through H.M. Stationery Office, the regulations and syllabus for Whitworth Scholarships to be offered in 1955. It is explained that the Minister of Education offers annually two Whitworth senior scholarships, each valued at £325 a year and tenable for two years, and five Whitworth scholarships, tenable for three years, at an annual value of £200. In addition, there are prizes, not exceeding ten in number, available to unsuccessful competitors for Whitworth scholarships whose work deserves recognition.

NEWCOMEN SOCIETY'S ANNUAL MEETING.—The annual general meeting of the Newcomen Society was held in London on Wednesday, November 10th. Mr. Rex Wailes was elected for a further year of office as president, and Mr. Charles E. Lee and Mr. L. E. Harris were elected vice-presidents. Mr. J. A. Crabtree and Mr. K. Gilbert were elected to vacancies on the council, and Mr. A. S. Crosley continues as the Society's honorary secretary. The business of the annual meeting was followed by a paper by Dr. Herbert Chatley, entitled, "Far Eastern Engineering." In Dr. Chatley's absence from the meeting on account of illness his paper was presented by Mr. L. E. Harris.

MR. CHRISTOPHER MCCREADY.—We record with regret the death, on November 11th, at Littlehampton, of Mr. Christopher McCready, who, for thirty-four years until his retirement in 1946, was on the staff of the traction department of the British Thomson-Houston Company, Ltd., at Rugby. He was seventy-three. Mr. McCready was born in Dublin and joined B.T.H. as a traction engineer in 1912. He received his early education in Dublin and at Monkton Combe School, Bath, and later returned to Ireland to study at the Royal College of Science, Dublin. After completing his training in 1901, Mr. McCready joined the Great Northern Railway of Ireland and was appointed chief assistant electrical engineer. During the first world war, Mr. McCready served in the Royal Naval Volunteer Reserve.

APPRENTICE TRAINING IN THE GAUGE AND TOOL INDUSTRY.—An interesting booklet has just been published by the Gauge and Tool Makers' Association entitled "Apprentice Training in the Gauge and Tool Industry." The booklet describes the methods of apprentice training adopted by small and large firms and is based upon a questionnaire sent to its member firms by the Association. It covers recruitment, selection of potential craftsmen, organisation of training, practical experience in the shops, technical training, and rewarding of craftsmanship. The booklet is essentially a practical approach to the subject and will be of interest and value to firms in the engineering industry generally, as well as to gauge and tool makers. Copies can be obtained at 1s. each from the Association's offices, Standbrook House, Old Bond Street, London, W.1.

BLIND PEOPLE IN THE ENGINEERING INDUSTRY.—The thirty-ninth annual report of St. Dunstan's, which is entitled *The Guiding Hand*, recalls that there was a time between the wars, when St. Dunstan's had little success in getting men and women into factories, mainly because of the mistaken idea of those who could have given them jobs that it would be far too dangerous, not only to the blind, but to the sighted workers as well. But, the report says, St. Dunstan's was determined to prove that the very opposite was actually the case, and by setting up its own machinery department at the training centre in which blinded soldiers operated routers and boring machines, a circular saw and a vertical belt sander, the men were not only taught to do an industrial job, and to do it thoroughly well, but they gained the invaluable experience, too, of getting used to the noise and atmosphere they would later have to contend with when they started work in a big factory. In 1940, when labour was short and urgently needed for war work, an aircraft factory asked for two blind men as an experiment. Within a year, thirty were at work in industry, and to-day 270 men and women from both world wars are employed in engineering workshops. Some are engaged, for example, on the assembly of heavy trolley wheels, on distributor heads for motor-cars, on heavy chains for use in agricultural machines and implements, on electrical switches used on vacuum cleaners, on the complete assembly of lawn mowers, and on the sub-assembly for gramophone motors, electric clocks, and so on.

Personal and Business

SILENTBLOC, Ltd., states that it is moving, on December 20th, to a new factory at Manor Royal, Crawley, Sussex.

MR. G. W. WELLS and MR. P. F. BENTON JONES have been appointed directors of the United Steel Companies, Ltd.

SIR RUPERT DE LA BERE, Bt., M.P., has been elected the first vice-president of the Institute of General Managers.

FRENCH RAILWAYS, Ltd., 179, Piccadilly, London, W.1, states that its telephone number has been changed to Hyde Park 9731.

P. W. ALLEN AND CO., 253, Liverpool Road, London, N.1, have been appointed United Kingdom agents for the "Bodson" endoscope.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that the telephone number of its Reading branch office has been changed to Reading 55074.

MR. C. K. TURNER-HUGHES has been appointed commercial manager of the aircraft electrical division of the Plessey Company, Ltd., Ilford, Essex.

HONEYWELL-BROWN, Ltd., has opened an area office at 95, Exchange Buildings, Mount Stuart Square, Cardiff, under the supervision of Mr. L. G. A. Gabe.

THE YALE AND TOWNE MANUFACTURING COMPANY announces that Mr. John Newble has been appointed advertising manager of its British materials handling division at Wednesfield, Staffs.

JOHN THOMPSON, Ltd., has opened a Newcastle branch office at "Ravenswood," Westfield Lane, Ryton-on-Tyne, Co. Durham (telephone, Ryton 482). Mr. S. A. H. Robinson is in charge of the office.

MR. H. G. MEADS has been appointed a director of Hoover, Ltd., and comptroller of the company's financial and administrative services. Mr. H. D. Vigers succeeds Mr. Meads as secretary of the company.

MR. J. N. DEAN has been appointed chairman of the Telegraph Construction and Maintenance Company, Ltd. Lord Colgrain has been appointed a director of the company to fill the vacancy caused by the death of his father.

TYER AND CO., Ltd., Dalston, London, E.8, announces the retirement of Mr. T. W. Ballard from the position of works manager to which he was appointed in 1925. Mr. Ballard has completed fifty-three years in the company's service.

A. A. JONES AND SHIPMAN, Ltd., Leicester, states that Mr. K. H. Bishop, general sales manager; Mr. F. W. Brooks, works accountant, and Mr. A. E. Pollard, assistant to the works director, have been appointed to the board.

MR. F. A. RAYFIELD, M.I.C.E., has been appointed deputy chief engineer of the London County Council, following the retirement of Mr. Forbes Jackson. Mr. Rayfield is the senior divisional engineer in the chief engineer's department.

GEO. SALTER AND CO., Ltd., West Bromwich, states that Mr. R. V. Collison has been appointed representative of the balance division in the West of England and South Wales. He will also represent the engineering division in Somerset, Devon and Cornwall.

GENERAL SIR WILLIAM MORGAN, G.C.B., chairman of Siemens Brothers and Co., Ltd., and Mr. John Innes, C.B., director of the Telegraph Construction and Maintenance Company, Ltd., have been appointed to the board of Submarine Cables, Ltd.

MR. J. A. WELLINGS has been appointed director and vice-president of Canadian Steel Improvement, Ltd., Etobicoke, Ontario. Mr. Wellings has been on the staff of High Duty Alloys, Ltd., Slough, since 1941, and has been divisional manager since 1948.

MR. J. C. MILNE, M.I.E.E., has been appointed managing director of the Electric Construction Company, Ltd., Wolverhampton, in succession to the late Mr. W. M. B. Furniss. Mr. Milne, who joined the company over twenty years ago, is the technical director.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., announces the following appointments:—Mr. J. V. Bigg, assistant chief engineer, condenser engineering department; Mr. J. A. Walker, assistant manager, Sheffield office, and Mr. K. Greenwood, district engineer, erection department, Glasgow.

ARPIC ENGINEERING, Ltd., Queenslie Estate, Glasgow, states that F. A. Gibson and Co. (Newcastle), Ltd., Haddricks Mill Road, South Gosforth, Newcastle upon Tyne, has been appointed sole agent for its products in the areas of Northumberland, Durham, Cumberland, Westmorland and the North Riding.

MR. KENNETH M. SCOTT has been appointed sales manager of Francis Morton and Co., Ltd. Mr. T. C. Grisenthwaite, special director and London manager, is retiring, for health reasons, at the end of the year, and Mr. Scott will then operate from the London office at 68, Avenue Chambers, 4, Vernon Place, Southampton Row, W.C.1.

THE MINISTRY OF SUPPLY announces that Dr. L. F. C. Northcott has been promoted to deputy chief scientific officer and has been appointed Senior Superintendent of Applied Research at the Armament Research Establishment, Fort Halstead. Dr. Northcott has been a superintendent in the Metallurgical Research Department of the Armament Research Establishment since 1947.

THE GOODYEAR TYRE AND RUBBER COMPANY (GT. BRITAIN), Ltd., states that Mr. A. H. Pendree has been appointed general sales manager, and Mr. Milton S. Meyer, director of sales. Mr. Donald Gow becomes financial director. These changes are consequent upon the recent appointment of Mr. A. S. Bishop to the post of managing director. Mr. Bishop has succeeded Mr. Walter A. Hazlett, who has become vice-president of the Goodyear Tire and Rubber Company Inc., in America.

SHORT BROTHERS AND HARLAND, Ltd., Belfast, announces a regrouping of its design teams. The technical staff is now divided into four groups—structures, project and aerodynamics, aircraft design and "Castlereagh"—under the overall direction of Mr. David Keith-Lucas, director and chief designer. The five members of the company principally involved in the new organisation are: Mr. R. Boorman, who is now chief structural engineer; Mr. C. D. Hatton, assistant chief engineer (aircraft); Mr. F. H. Robertson, chief project designer; Mr. K. L. C. Legg, structural development engineer, and Mr. F. P. Youens, advance projects engineer.

MINE SAFETY APPLIANCES COMPANY, Ltd., Queenslie Industrial Estate, Glasgow, has purchased from Thomas A. Edison, Ltd., the miners' electric cap lamp manufacturing facilities situated in Glasgow. Under a licensing agreement made between the two companies, Mine Safety Appliances Company, Ltd., heretofore distributors of Edison cap lamps in world markets other than the Western Hemisphere, will now also produce the Edison lamps for these markets, in Britain. Other interests and operations of Thomas A. Edison, Ltd., in Britain are not affected by this change. Mr. R. Crawford, managing director of Mine Safety Appliances Company, Ltd., will be responsible for the management of the combined undertaking.

Contracts

MODERN WHEEL DRIVE, Ltd., has received an order for a twin engine oil-operated reverse reduction gear for a cargo ship building for the Whitepass and Yukon Corporation. The gear will take power from two Mirrlees mark J.S.S. eight-cylinder, four-stroke diesel engines, each rated at 955 b.h.p. at 800 r.p.m.

WOODALL-DUCKHAM CONSTRUCTION COMPANY, Ltd., 63–77, Brompton Road, London, S.W.3, has received from the South African Iron and Steel Industrial Corporation, Ltd., two orders for coke-oven plants, the approximate total value of which amounts to £1,750,000. One plant is to be built at the Vanderbijl Park works and the other at the Pretoria works.

THE BRITISH ELECTRICITY AUTHORITY has placed contracts during the past month for power stations, transforming stations and transmission lines, amounting in the aggregate to £3,747,776. The principal contracts include: Brighton "B" power station, two 72MVA, 34·8/11·6kV generator transformers (English Electric Company, Ltd.); Brimsdown "B" power station, near Enfield, 33kV and low-voltage cables and accessories (Aberdare Cables, Ltd.); Willington "A" power station, near Derby, superstructure (Marples, Ridgway and Partners, Ltd.); Lincoln power station, administration block (Wm. Moss and Sons, Ltd.); Bold "A" power station, St. Helens, two 36MVA, 11·8/33·4 generator transformers (Metropolitan-Vickers Electrical Company, Ltd.); Portobello power station, Edinburgh, circulating water pumps, pipework, valves and strainers (Drysdale and Co., Ltd.); Bristol and Birmingham Grid control areas, standardised indication and telephone equipment (General Electric Company, Ltd.); Thames North and Leeds Grid control areas, standardised indication and telephone equipment (Standard Telephones and Cables, Ltd.); Agecroft substation, Salford, 132kV, 3500MVA switchgear (Metropolitan-Vickers Electrical Company, Ltd.); Penwortham substation, 275kV, 7500MVA switchgear (Ferguson Pailin, Ltd.); Rochdale substation, site and foundation works (Leonard Fairclough, Ltd.); Warrington substation, modifications to 132kV switchgear and equipment (Ferguson Pailin, Ltd.), and Dalmarnock substation, 132kV, 2500MVA switchgear (Metropolitan-Vickers Electrical Company, Ltd.).

British Patent Specifications

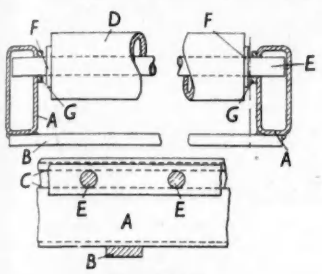
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

CONVEYORS AND TRANSPORTERS

717,102. October 13, 1952.—ROLLER CONVEYORS, Parker Mitchell Engineering Company, Ltd., and William Mitchell Parker, Wallace James Parker, and John Beaton Boyle, all of Spiersbridge Industrial Estate, Thornliebank, Glasgow.

The invention has reference to roller conveyors of the type comprising a series of parallel rollers, each carried by a spindle supported by a pair of parallel stringers spaced by transverse bars. In the construction shown in the drawing the conveyor is formed of two parallel stringers *A* of box cross-section, spaced by transverse bars *B* to which they are welded. The opposed sides of the two stringers are provided with gaps *C* near the upper faces. Each roller *D* is



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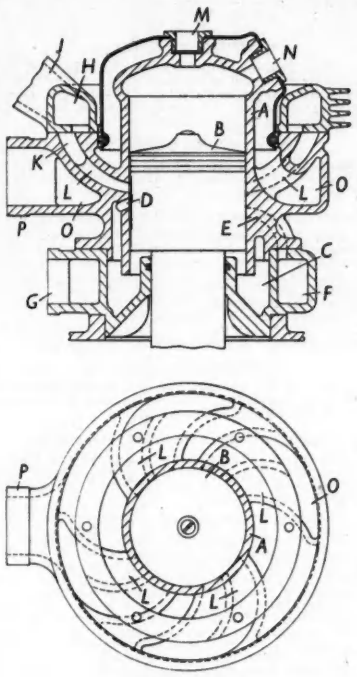
mounted on its spindle *E* on rollers or other anti-friction bearings *F*, and the ends of the spindles are fitted into holes punched in spacer strips *G*. The ends of the spindles project beyond the spacer strips and pass through the gaps into the stringers, their extremities being then in close proximity to the inner faces of the outer sides of the stringers. In assembling the conveyor the spindles *E* are inserted through the holes in the spacer strips *G* and the projecting ends of the spindles slid into the longitudinal gaps *C* in the stringers, the spacer strips then bearing against the opposed faces of the stringers. Axial movement of the rollers is prevented by the extremities of the spindles bearing on the inner faces of the outer sides of the stringers. Should it be desired to form a conveyor with differently spaced rollers, the rollers with spacer strips are withdrawn from their stringers, the spindles inserted in different holes in the spacer strips or inserted in the holes formed in another set of spacers. The projecting ends of the spindles are then slid into the gaps in the stringers, the spacer strips holding them in spaced relationship. A modified construction of conveyor is also shown in the specification.—*October* 20, 1954.

INTERNAL COMBUSTION ENGINES

717,168. September 26, 1951.—IMPROVED SCAVENGING, Gilbert Edgar Manley, The Old Rectory, Henley-in-Arden, Warwick.

The invention is designed to enable the energy of the exhaust gases to be utilised in an improved manner for scavenging the engine cylinder. As shown by the drawing, the cylinder *A* contains a piston *B*. At the lower end of the cylinder is arranged an air compression chamber *C* which communicates with the cylinder by the ports *D*. Air is supplied to the chamber *C* from the atmosphere through the usual non-return valve. Further, an annular air chamber *F* communicates with the cylinder through ports *E*, and with the atmosphere through an inlet *G*. Around the cylinder is arranged an annular exhaust gas collector *H* having a discharge outlet *J*. Also around the cylinder is an annular swirl chamber *K*. Exhaust gas enters this chamber from the cylinder through a number of curved gas expansion passages *L*, each having one end open to the cylinder, and the other end open to the swirl chamber. The liquid fuel injection nozzle and sparking plug are secured to the cylinder at the positions *M* and *N*. Cooling water is admitted to the engine jacket *O* at *P*. During the working stroke of the engine air is compressed in the air compression chamber *C*. Towards the end of this stroke the exhaust passages *L* are opened for the release of the exhaust gases. Immediately after, air under pressure is admitted to the cylinder from the air compression chamber *C* through the ports *D*, and later atmospheric air is induced into the cylinder through the ports *E*. During the return stroke, the air in the cylinder is compressed by the piston, and when the piston approaches the upper end of this stroke air is admitted to the air compression chamber *C* through the non-return valve. The essential feature of the invention is the exhaust gas swirling means. Exhaust gas entering the passages *L* from the cylinder is directed obliquely into the swirl chamber *K* at high velocity. After entering the chamber the gases swirl around the chamber, and form therein a continuously rotating mass having its axis coincident with that of the cylinder. The swirling gases have



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access to the collector chamber *H* through the orifice or orifices. However, this orifice, or each such orifice, is situated at the inner side of the swirl chamber *K*, and thus has little or no effect on the swirling motion of the gases in the swirl chamber. The effect of the swirling motion is to induce a rapid and efficient evacuation of the cylinder, and thereby effectively scavenge the cylinder. An alternative design, with valve-controlled exhaust discharge, is also shown in the specification.—*October* 20, 1954.

CHEMICAL ENGINEERING

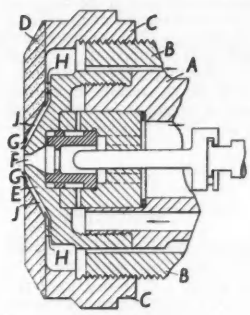
716,264. May 16, 1952.—SULPHUR RECOVERY, The Power-Gas Corporation, Ltd., Parkfield Works, Stockton-on-Tees. (*Inventors: Geoffrey Milner and Arthur John Brockwell.*)

The invention concerns improvements in and relating to sulphur recovery. For converting 3000 cubic feet of pure hydrogen sulphide per hour 1000 cubic feet is supplied to the combustion chamber of a fire-tube boiler, with 5640 cubic feet of air. On leaving the boiler the products of combustion are mixed with the remaining 2000 cubic feet of hydrogen sulphide, and pass to the first stage of a catalytic converter, operating at about 600 deg. Fah. The gas mixture is then cooled to just above its dew point in a heat exchanger, and the sulphur vapour is removed by molten sulphur in a counter-current sulphur scrubber. The exit gas with some 900 cubic feet per hour of sulphur dioxide is recovered by scrubbing the tail gases. The mixture is then heated in an exchanger to about 550 deg. Fah., and the sulphur vapour, on leaving the second converter, is washed with liquid sulphur in a further scrubber, and the gas mixture is then passed to a cooling tower. It then passes to a lead-lined tower containing iron oxide to remove the hydrogen sulphide. The exit gases from this tower contain about 4140 cubic feet per hour of nitrogen, with about 940 cubic feet of sulphur dioxide. This tail gas is then led to an absorber, in which the sulphur dioxide is absorbed by a suitable absorber, such as dimethylaniline. The residual nitrogen then passes to the atmosphere through a stack and the sulphur dioxide is liberated and returned to the main gas stream as described above, to provide the excess of sulphur dioxide required in the process.—*September* 29, 1954.

BURNERS AND SPRAYERS

717,071. May 28, 1952.—OIL SPRAY BURNER NOZZLES, The Parsons and Marine Engineering Turbine Research and Development Association, Pametrada Research Station, Wallsend. (*Inventor: Robert Francis Darling.*)

The object of the invention is to provide improved oil spray burners which are cooled and kept clean. As shown in the drawing, an oil sprayer body *A* is in a housing *B* carrying a screwed ring *C* furnished with a cover plate *D*, which is spaced from the tip of



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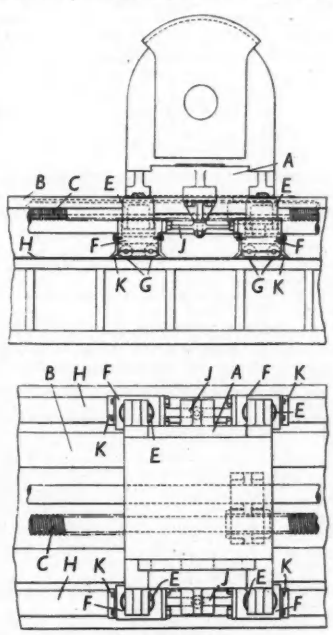
a sprayer nozzle cap *E* embodying a fuel outlet orifice *F*. The cover plate has an orifice *G* which is larger than the fuel orifice *F* and the cover plate *D* which is concentric with the cap *E* is composed of porous steel. Compressed air is supplied to the space *H* between the cover plate *D*, ring *C* and nozzle cap *E*, and some of it flows through the annular opening *J* between the cap and the cover plate to the air orifice *G*, while the remainder permeates through the interstices of the cover plate *D*. Thus, some of the compressed air is directed across the outlet of the fuel orifice *F*, which is thereby kept free from carbon, while the remainder permeates through the cover plate *D*, cooling it and preventing carbon from depositing on a substantial area surrounding the fuel orifice.—*October* 20, 1954.

MACHINE TOOLS

716,907. April 9, 1952.—MACHINE TOOLS WITH HORIZONTALLY MOVED SADDLES, The Parsons Marine Steam Turbine Company, Ltd., Turbinia Works, Wallsend-on-Tyne. (*Inventor: Louis Mortimer Douglas.*)

The invention relates to machine tools in which a saddle is arranged to move horizontally on guideways or slides. A machine tool embodying one form of the invention is shown. A hob saddle *A*, moved longitudinally in relation to a fixed bed *B* by means of a feed screw *C*, is urged upwards by means of four compression springs housed between two telescopic members *E* and *F* forming part of a bogie element carried on a pair of rollers *G*. The rollers rest on



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surfaces *H* rigid with the bed, but separate from the guideways carrying the saddle *A*. The four bogie elements are secured to one another and to the saddle by means of frame members *J*. Guards provided for the ends of the bogies to prevent any foreign matter, such as metal cuttings from intruding between the rollers and the track, comprise blades *K* at the end of each bogie having very small clearance from the track, as shown. In this construction the main guides are not interfered with and are left to perform their function of controlling accurately the longitudinal motion of the saddle and any foreign matter getting

on to the slides will be pushed away by the saddle. The effect of foreign matter on the auxiliary tracks is negligible; these tracks have no influence upon the guidance of the saddle motion and, in fact, need not have the accuracy which is necessary for the saddle slides. The weight relieving springs have considerable compression, so that the slight variation in this compression resulting from any intruded matter merely results in a slight variation in the amount of weight relief and has no influence whatever on the functioning of the guides.—*October* 20, 1954.

Catalogues

BRITISH JEFFREY DIAMOND, Ltd., Wakefield, Yorks.—Publication No. 1502, "Scraper Chains."

WODEN TRANSFORMER COMPANY, Ltd., Moxley Road, Bilston, Staffs.—Folder on screen heating.

JOHN HARPER AND CO., Ltd., Albion Works, Willenhall, Staffs.—Leaflet on cast iron resistance grids.

BIRLEC, Ltd., Erdington, Birmingham.—Booklet describing vertical forced air circulation furnaces.

CRYPTON EQUIPMENT, Ltd., Bridgwater, Somerset.—List TT954, dealing with systematic engine diagnosis.

HERBERT TERRY AND CO., Ltd., Redditch, Worcs.—Leaflet describing the range of Belleville washers supplied.

AUTOMATIC TELEPHONE AND ELECTRIC COMPANY, Ltd., Strowger House, 8, Arundel Street, London, W.C.2.—Booklet illustrating "Electro-matic" vehicle-actuated signals.

ZINC ALLOY DIE CASTERS' ASSOCIATION, Lincoln House, Turl Street, Oxford.—Latest publication of the Association, entitled *Big Savings with Small Zinc Alloy Die Castings.*

THE EXCELSIOR MOTOR COMPANY, Ltd. (Industrial Truck Division), Kings Road, Tyseley, Birmingham, 11.—Leaflet describing "Pyramid" lightweight motor trucks.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Tues., Nov. 30*th.*—N.W. SECTION: Reynolds' Hall, College of Technology, Sackville Street, Manchester, "Electronics and the Wind Tunnel," G. J. Scoles, 7 p.m.

Thurs., Dec. 2*nd.*—MERSEYSIDE SECTION: College of Technology, Byron Street, Liverpool, 3, "Electronics in Materials Handling," L. Landon Goodman, 7 p.m.——SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Some Interesting Applications of Electronics to Photography," D. M. Neale, 7 p.m.

Wed., Dec. 8*th.*—N.E. SECTION: Neville Hall, Westgate Road, Newcastle upon Tyne, "Logic, Algebra and Relays," Emrys Williams, 6 p.m.——W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Industrial Applications of Electronic Control," J. A. Sargrove, 7.15 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed. and Thurs., Dec. 8*th and* 9*th.*—Cairn Hydro Hotel, Harrogate, Conference on the Industrial Aspects of Air Pollution.

ENGINEERS' GUILD

Thurs., Dec. 2*nd.*—ORDINARY MEETING: Caxton Hall, Caxton Street, Westminster, London, S.W.1, "The Profession of the Land," P. H. White, 6 p.m.

Wed., Dec. 8*th.*—16, Queen Anne's Gate, London, S.W.1, Annual General Meeting, 5.45 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Nov. 26*th.*—BATH AND BRISTOL CENTRE: S.W. Electricity Board, Lecture Theatre, Old Bridge Street, Bath, "Lighting for Enjoyment," T. O. Freeth, 7 p.m.

Mon., Nov. 29*th.*—LEEDS CENTRE: Lecture Theatre, Yorkshire Electricity Board, Ferensway, Hull, Four short papers on Industrial Lighting, by Members of the Centre, 7.30 p.m.

Wed., Dec. 1*st.*—EDINBURGH CENTRE: Manor Club, 12, Rothesay Place, Edinburgh, "What Do We Know About Lighting," R. J. Fothergill, 7 p.m.——SWANSEA GROUP: S. Wales Electricity Board's Demonstration Theatre, The Kingsway, Swansea, "Lighting for Enjoyment," T. O. Freeth, 6.30 p.m.

Thurs., Dec. 2*nd.*—NOTTINGHAM CENTRE: Demonstration Theatre, E. Midlands Electricity Board, Smithy Row, Nottingham, "A New Approach to Lighting Design," W. Robinson, 6 p.m.——CARDIFF CENTRE: S. Wales Electricity Board's Demonstration Theatre, The Hayes, Cardiff, "Lighting for Enjoyment," T. O. Freeth, 5.45 p.m.

Tues., Dec. 7*th.*—STOKE-ON-TRENT GROUP: Lecture Hall, Midlands Electricity Board, 31, Kingsway, Stoke-on-Trent, "Marine Lighting," T. Catten, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Nov. 26*th.*—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Laundries," G. N. Freck, 7.30 p.m.

Mon., Nov. 29*th.*—W. AND E. YORKSHIRE BRANCH: The University, Leeds, "Fuel Injection Equipment for High-Speed Oil Engines," W. H. Simpson, 7.30 p.m.

Wed., Dec. 1*st.*—LEICESTER BRANCH: College of Art and Technology, The Newarkes, Leicester, Members' Papers, 6.30 p.m.——SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "Prevention of Industrial Accidents," T. W. Thompson, 7.30 p.m.

Thurs., Dec. 2*nd.*—PETERBOROUGH BRANCH: Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, "Railway Electrification, 7.30 p.m.

Tues., Dec. 7*th.*—EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, "Lighting in Industry," Charles J. King, 7 p.m.——LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Heat-Treatment of Steel," C. Haywood, 7 p.m.

INSTITUTE OF FUEL

Fri., Dec. 3*rd.*—S. WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "Sulphur Removal and Recovery from Fuels," J. G. King, 6 p.m.——SCOTTISH SECTION: North British Hotel, Edinburgh, "The Constitution of Coal: Modern Theories," A. Whitaker, 7 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Nov. 26*th.*—MERSEYSIDE AND N.W. SECTION JUNIOR LECTURE: Technical College, Barrow-in-Furness, "Air Conditioning of Ships," J. K. W. Macvicar, 7.30 p.m.

INSTITUTE OF METALS

To-day, Nov. 26*th.*—4, Grosvenor Gardens, London, S.W.1 Meeting for the benefit of Members unable to take part in the Autumn Meeting in Switzerland. 10 a.m., Discussion on "Preferred Orientation"; 2.30 p.m., Discussion on "Corrosion and Staining of Aluminium Alloys."

INSTITUTE OF PETROLEUM

Wed., Dec. 8*th.*—26, Portland Place, London, W.1, "Design and Operation of a Fluidised Pilot Plant for the Fischer-Tropsch Synthesis," C. C. Hall and A. H. Taylor, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., Dec. 1*st.*—EASTERN CENTRE: Museum Art Gallery, Peterborough, "The Development of the Gas Turbine and its Application to Road Transport," P. A. Phillips, 7 p.m.

Mon., Dec. 6*th.*—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Electrical Equipment as Applied to the Heavy Commercial Vehicle," C. T. Corney and A. V. Waters, 7.30 p.m.

Tues., Dec. 7*th.*—N.W. CENTRE: Victoria Station Hotel, Preston, "Diesel Maintenance," H. L. Parrish, 7.30 p.m.

INSTITUTE OF WELDING

Thurs., Dec. 2*nd.*—N. LONDON BRANCH: Manson House, Portland Place, London, W.1, "The Composition of Weld Metal," W. P. Van-Den Blink, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Dec. 1*st.*—S. WALES CENTRE GRADUATES' AND STUDENTS' SECTION: University College, Cathays Park, Cardiff, "Some Observations on the Design and Commissioning of Chemical Plants," B. L. Budd, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Nov. 30*th.*—ROAD MEETING: Great George Street, Westminster, London, S.W.1, "Prestressed Units for Short-Span Highway Bridges," A. D. Holland, 5.30 p.m.

Wed., Dec. 1*st.*—MIDLANDS ASSOCIATION: Midland Institute, Birmingham, "Nuclear Reactors and Power Production," Sir Christopher Hinton, 6 p.m.

Thurs., Dec. 2*nd.*—N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Peace-Time Activity of the Corps of Royal Engineers," A. N. Anstruther, 6.30 p.m.

Tues., Dec. 7*th.*—STRUCTURAL AND BUILDING MEETING: Great George Street, Westminster, London, S.W.1, Symposium on "High Buildings," Sergei Kadleigh, A. L. L. Baker, A. W. Skempton and S. J. Chamberlain, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Nov. 30*th.*—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, Discussion on "The Servicing of Electronic Measuring Instruments and its Effect on Their Design," opened by Denis Taylor, 5.30 p.m.——LONDON STUDENTS' SECTION: R.E.M.E. Training Centre, Hazebrouck Barracks, Arborfield, Berks, Film Evening, 7 p.m.

Wed., Dec. 1*st.*—RADIO SECTION: Savoy Place, London, W.C.2, "Vertical Radiation Patterns of Medium-Wave Broadcasting Aerials," H. Page and G. D. Monteath, 5.30 p.m.——S.W. SCOTLAND SUB CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Some Applications of the Electrolytic Tank to Engineering Design Problems," H. Diggle and E. R. Hartill, 7 p.m.

Thurs., Dec. 2*nd.*—ORDINARY MEETING: Savoy Place, London, W.C.2, "The Electrification of the Manchester–Sheffield–Wath Lines, Eastern and London Midland Regions, British Railways," J. A. Broughall and K. J. Cook, 5.30 p.m.

Mon., Dec. 6*th.*—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "The Applications and Limitations of Electronic and Other Computers," opened by L. G. Brazier, 5.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., Dec. 6*th.*—Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "Control of Electrical Circuits," J. Teasdale, 7.15 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., Nov. 30*th.*—COVENTRY BRANCH: Room A5, Technical College, Coventry, "Recent Developments in Metrology, with Special Reference to Interferometry," W. Foster, 7.30 p.m.

Wed., Dec. 1*st.*—BIRMINGHAM BRANCH: Chamber of Commerce, New Street, Birmingham, "Dynamic Balancing," A. Binns, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Nov. 30*th.*—39, Elmbank Crescent, Glasgow, "Components of the Propulsive Efficiency of Screw Vessels," G. Johnson, 7.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 26*th.*—GENERAL MEETING arranged in conjunction with the APPLIED MECHANICS' GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Dynamic Stresses in Electric Overhead Travelling Cranes Due to the Hoisting and Lowering of Loads," E. Lightfoot and B. L. Clarkson, 5.30 p.m.

Tues., Nov. 30*th.*—STEAM GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Planning and Operation of Maintenance Schedules for Steam Power Plants," 6.45 p.m.

Wed., Dec. 1*st.*—MIDLAND BRANCH: Midland Institute, Birmingham, "Nuclear Reactors and Power Production," Sir Christopher Hinton (presented by J. M. Kay), 6 p.m.——SOUTHERN BRANCH: Dolphin Hotel, Chichester, "Some Engineering Aspects of a Public Water Supply," T. Irvine Hudson, 6 p.m.——WESTERN BRANCH: Grand Hotel, Bristol, "The Accountancy Service to Works Management," C. E. Power, 7 p.m.——YORKSHIRE GRADUATES' SECTION: The University, Leeds, "Development of Steam Turbines," A. P. Houghton, 7.30 p.m.

Thurs., Dec. 2*nd.*—INTERNAL COMBUSTION ENGINE GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, "The Relative Merits of Full-Flow and Bypass Filtration in High-Speed-Engine Lubrication Systems," 6.45 p.m.——N.W. BRANCH: Engineers' Club, Albert Square, Manchester, "Fuel Systems and Controls for Marine Gas Turbines," R. F. Darling; "Main Propulsion Gas Turbine Set for the Oil Tanker 'Auris,'" B. E. G. Forsling, 6.45 p.m.——SCOTTISH BRANCH: Royal Technical College, George Street, Glasgow, "Shrink Fit Investigations on Simple Rings and on Full-Scale Crankshaft Webs," A. S. T. Thomson, A. W. Scott and C. M. Moir, 7.30 p.m.——E. MIDLANDS GRADUATES' SECTION: College of Technology, The Newarkes, Leicester, "Combustion Systems for Gas Turbine Aero-Engines," S. L. Bragg, 7.15 p.m.——WESTERN GRADUATES' SECTION: Swindon Engineering Society's Rooms, Eulyn Square, Swindon, "Planned Maintenance," R. K. B. Lyne, 7.30 p.m.

Fri., Dec. 3*rd.*—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, "The Roll-Setting Method of Automatic Control of Gauge in Hot and Cold Rolling Mills," R. L. Sims and K. H. Slack, 5.30 p.m.——SCOTTISH BRANCH: Sir Robert Gordon's Technical College, Aberdeen, "Shrink Fit Investigations on Simple Rings and on Full-Scale Crankshaft Webs," A. S. T. Thomson, A. W. Scott and C. M. Moir, 7.30 p.m.

Mon., Dec. 6*th.*—N.E. BRANCH: Neville Hall, Newcastle upon Tyne, "Inspection, Explosion and Breakdown of Pressure Vessels," J. Eyers, 6 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Nov. 30*th.*—LUTON SECTION: Pink Room, W. H. Allen, Sons and Co., Ltd., Bedford, "Noise and Vibration in Machinery," A. J. King, 7.15 p.m.

Wed., Dec. 1*st.*—HALIFAX SECTION: George Hotel, Huddersfield, "Production Panel," 7.15 p.m.——NOTTINGHAM SECTION: Victoria Station Hotel, Milton Street, Nottingham, "Work Study Techniques," L. G. Humble, 7 p.m.——WOLVERHAMPTON SECTION: Technical College, Wulfruna Street, Wolverhampton, "Control of Production as Applied to the Manufacture of Small I.C. Engines," D. Dudfield, 7.15 p.m.

Thurs., Dec. 2*nd.*—MANCHESTER GRADUATE SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, "The Electronic Control of Machine Tools," E. Heys, 7.15 p.m.

Fri., Dec. 3*rd.*—NORWICH SECTION: Assembly House, Theatre Street, Norwich, "Planned Maintenance," O. F. Lewis, 7.30 p.m.——W. WALES SECTION: Central Library, Alexandra Road, Swansea, "Planning for Production," B. E. Stokes, 7.30 p.m.

Mon., Dec. 6*th.*—WESTERN GRADUATE SECTION: Grand Hotel, Broad Street, Bristol, 1, "How Much Management Can We Afford?" Mrs. Ruby A. Ord, 7.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Dec. 6*th.*—PRESTON BRANCH: Bull and Royal Hotel, Church Street, Preston, "Some Observations on the Behaviour of Non-Inflammable Belting on Underground Conveyors," D. N. Walker and L. T. Hems, 7.15 p.m.——MERSEYSIDE BRANCH: Committee Room, Liverpool Corporation Passenger Transport Office, 24, Hatton Garden, Liverpool, "Using Man-Made Fibres in the Rubber Industry," J. W. Illingworth, 7 p.m.——N.E. BRANCH: Neville Hall, Mining Institute, Newcastle upon Tyne, "Rubber and the Synthetic Elastomers as Adhesives," L. E. Puddefoot, 7 p.m.——BURTON-ON-TRENT BRANCH: Midland Hotel, Station Street, Burton-on-Trent, "Modern Trends in Rubber Compounding," J. Mason, 7.15 p.m.

INSTITUTION OF SANITARY ENGINEERS

Thurs., Dec. 2*nd.*—Caxton Hall, Caxton Street, Westminster, London, S.W.1, "Biological Sewage Filtration and Vacuum Dewatering of Sludge: Experimental Work at Reading, 1949–54," D. H. Barraclough, 6 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Nov. 26*th.*—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "Structural Use of Timber," S. Woolf, 6 p.m.

Mon., Nov. 29*th.*—LANCASHIRE AND CHESHIRE BRANCH: Reynolds' Hall, College of Technology, Manchester, "The Design Features and Collapse Investigation of the Tacoma Narrows Bridge," S. M. Copper, 6.30 p.m.

Wed., Dec. 1*st.*—NORTHERN COUNTIES BRANCH: Neville Hall, Newcastle upon Tyne, "Lackenby Steelworks," A. P. Clarke, 6.30 p.m.

Fri., Dec. 3*rd.*—WESTERN COUNTIES BRANCH: University of Bristol, Geology Lecture Theatre, Bristol, "Highlights in an Engineer's Life," J. Guthrie Brown, 6 p.m.

IRON AND STEEL INSTITUTE

Wed. and Thurs., Dec. 1*st and* 2*nd.*—The Hoare Memorial Hall, Church House, Westminster, London, S.W.1, Symposium on "Powder Metallurgy, 1954," in association with the Institute of Metals.

JUNIOR INSTITUTION OF ENGINEERS

Wed., Dec. 1*st.*—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Chairman's Address, "Tropical Aquaria Electrical Apparatus," C. H. Crawford, 7 p.m.

Fri., Dec. 3*rd.*—Pepys House, 14, Rochester Row, London, S.W.1, Film Evening, "The Manufacture of Portland Cement," and "Handling Concrete on Housing Sites," introduced by S. Penberthy, 7 p.m.

Mon., Dec. 6*th.*—N.W. SECTION: Engineers' Club, Albert Square, Manchester, "Boring Machines," W. Tomkinson, 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Nov. 26*th.*—Engineers' Club, Albert Square, Manchester, "Submarine Telegraph and Telephone Cables," F. Mattingley, 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 26*th.*—Mining Institute, Newcastle upon Tyne, "The Use of a Digital Computer with Particular Reference to the Analysis of Structures," R. K. Livesley, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Mon., Dec. 6*th.*—N.W. BRANCH: College of Technology, Sackville Street, Manchester, Film Evening, 6.45 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Dec. 2*nd.*—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, "Seaplanes: A Survey of the Development of Water-Based Aircraft Design," R. F. R. Storey, 7.30 p.m.

ROYAL SOCIETY OF ARTS

Wed., Dec. 1*st.*—LLEWELLYN B. ATKINSON MEMORIAL LECTURE: John Adam Street, Adelphi, London, W.C.2, "The Insulation of Modern Submarine Cable," J. V. Dean, 2.30 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., Dec. 6*th.*—The University Building, St. George's Square, Sheffield, Annual General Meeting, "The Park Gate 11in Continuous Bar Mill," W. Udall, 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Thurs., Dec. 2*nd.*—ROAD AND BUILDING MATERIALS GROUP: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Physico-Chemical Properties of Bitumens as Used in Mastic Asphalt," D. C. Broome, 6 p.m.

SOCIETY OF INDUSTRIAL ENGINEERS

Sat., Dec. 4*th.*—The Building Centre, 425, Sauchiehall Street, Glasgow, "Machine Loading," W. D. Stafford, 10 a.m.

WOMEN'S ENGINEERING SOCIETY

Tues., Nov. 30*th.*—MANCHESTER BRANCH: Gas Theatre, Town Hall, Manchester, "The Manufacture of Fashion Jewellery and Accessories," Miss D. Pile, 7 p.m.